PhD Dissertation Draft

by Songkomkrit Chaiyakan

Submission date: 24-Jan-2025 10:32PM (UTC+0900)
Submission ID: 2555364048
File name: main_phd.pdf (1.19M)
Word count: 113363
Character count: 525491

HIGHLY ACCURATE LINEAR CLASSIFIER WITH APPLICATIONS IN HEALTH INSURANCE COVERAGE

Songkomkrit Chaiyakan

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program
in Business Analytics and Data Science
Graduate School of Applied Statistics
National Institute of Development Administration
Academic Year 2024

Thesis Title	HIGHLY ACCURATE LINEAR CLASSIFIER WITH APPLICATIONS IN HEALTH INSURANCE COVERAGE
By	Songkomkrit Chaiyakan
Field of Study	Business Analytics and Data Science
Thesis Advisor	Assistant Professor Preecha Vichitthamaros, Ph.D.

Accepted by Graduate School of Applied Statistics, National Institute of Development Administration in Partial Fulfillment of the Requirements for the Doctoral Degree

.... Dean of Graduate School of Applied Statistics
(Siwiga Dusadenoad, Ph.D.)

DISSERTATION COMMITTEE

.... Chairman
(Associate Professor Ohm Sornil, Ph.D.)

.... Thesis Advisor
(Assistant Professor Preecha Vichitthamaros, Ph.D.)

.... Examiner
(Associate Professor Surapong Auwatanamongkol, Ph.D.)

.... Examiner
(Associate Professor Pachitjanut Siripanich, Ph.D.)

.... External Examiner
(Assistant Professor Boonyarit Intiyot, Ph.D.)

6310432002: MAJOR BUSINESS ANALYTICS AND DATA SCIENCE

KEYWORDS: BOX CLASSIFICATION / OPTIMIZATION / 0-1 MIXED INTEGER PROGRAMMING / DIMENSIONALITY REDUCTION / CONTINUOUS DATA / CATEGORICAL DATA / HEALTH INSURANCE

SONGKOMKRIT CHAIYAKAN : HIGHLY ACCURATE LINEAR CLASSIFIER WITH APPLICATIONS IN HEALTH INSURANCE COVERAGE. ADVISOR : Assistant Professor Preecha Vichitthamaros, Ph.D., 483 pp.

This work proposes a multiclass box classifier both theoretically and empirically proven to produce the highest training accuracy through the rigorous formulation of 0-1 mixed integer programming problem. It can also determine significant factors. Unlike a decision tree classifier well-known for simplicity and fast execution, the proposed classifier has control over a maximal number of features of interest, whether continuous or categorical, and a number of splitting values on all features. The use of this method is illustrated on 2020 Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC) health insurance dataset with, as a result of the exponential time complexity of the model, only three independent variables univariately preselected by the SelectKBest technique. Compared to decision tree classifiers of different depths, the proposed classification model can keep a balance between the number of total splitting values and the number of decision boxes, and it achieves a relatively high training accuracy at the expense of significantly high computational time and storage usage. Nonetheless, both give the same set of contributing factors. The fast algorithm of decision box merging is also suggested when the number of selected features can be further reduced after optimization.

Graduate School :	Applied Statistics	Student's Signature ....
Field of Study :	Business Analytics and Data Science	Advisor's Signature ....
Academic Year :	2024	

Acknowledgements

I would like to express my thankfulness to my dissertation advisor Assistant Professor Preecha Vichitthamaros for his consistent help throughout the entire dissertation. Further thanks extend to Jessica Barnett and Laryssa Mykyta, U.S. Census Bureau, for their advice on public use files and technical documentation of Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC) health insurance datasets. I am especially indebted to my parents, Songsak and Kanjanee, and to my sister, Kanokkan, for their continual support, encouragement, and love. This dissertation is partially supported by National Institute of Development Administration for publication and Google Cloud research program for free access to a remote compute engine.

Contents

List of Tables

List of Figures

List of Codes

Nomenclature

$\tilde{d}$	full dimension of given training instances
d	number of both continuous and categorical features of interest
d_{cat}	number of categorical features of interest
$\tilde{\mathcal{C}}_{\text{cont}}$	index set of given continuous features
$\tilde{\mathcal{C}}_{\text{cat}}$	index set of given categorical features
$\mathcal{C}_{\text{cont}}$	index set of new continuous features before optimization
$\mathcal{C}_{\text{cat}}$	index set of intermediate categorical features before optimization
$\tilde{x}^i$	given training instance i
x^i	training instance i as a classifier input of lower continuous and full categorical dimensions
x^i_j	value of feature j of instance x^i
y^i_k	whether a given instance $\tilde{x}^i$ is in class k
$c_{j,\tilde{j}}$	whether a new continuous feature j comes from an original continuous feature $\tilde{j}$
f_j	whether categorical feature j is selected or, equivalently, significant
p_j	number of splitting values on feature j
$b_{j,q}$	q^{th} splitting value on continuous feature j
u_j	new group labels on categorical feature j
v_{j,x^i_j}	new group label of instance x^i_j on categorical feature j
B	number of total decision boxes
S_β	β^{th} decision box
$\alpha^i_{j,q}$	whether x^i_j is in open interval $(b_{j,q}, b_{j,q+1})$
M	sufficiently large positive number
m_j	sufficiently small positive number on feature j that can distinguish individual feature values of x^i_j
$l^i_{j,q}$	$\alpha^i_{j,q}(b_{j,q} + m_j)$
$r^i_{j,q}$	$\alpha^i_{j,q}(b_{j,q+1} - m_j)$
γ^i_β	whether instance x^i_j is in decision box S_β
Θ_β	set of most frequent classes in decision box S_β
h_β	negative value of number of correctly classified training instances

CHAPTER I

INTRODUCTION

Social science research heavily relies on the traditional use of logistic regression or structural equation modeling (SEM) to explore or confirm the linkage between multiple factors with the ultimate goal of causal explanation. In addition to the significance test of coefficients, the utilization of mediators, moderators, confounders and covariates provides the convincing magnitude and direction of estimated effects. On the rare occasion of classification with numerous independent variables measured on nominal scales, the excessive number of required dummy variables nevertheless imposes a limitation on these two approaches.

To address this problem, classification algorithms in machine learning are used to identify key characteristics of a separate group despite lack of important statistical tests. For example, a decision tree constructs a set of rules individually formed by minimal attributes to fully describe a training data, and a neural network employs a hidden layer to account for nonlinear interaction between attributes and therefore increases model accuracy. The first maximizes an information gain, whereas the latter minimizes a residual sum of square. Both objective functions are usually smooth and enable real-time data processing.

Despite their advantage, a decision tree and a neural network may provide undesirable inaccuracy. As a result, a linear classifier developed from conventional support vector machine (SVM) through the application of 0-1 mixed integer linear programming (MILP) will be proposed in the dissertation to ensure maximum accuracy without overfitting. In this case, external testing seems redundant unless a training data contains an outlier. As early-stage research, the classifier will serve no purpose of real-time analytics. This modified approach will be adopted for illustrative purposes to examine contributing factors on coverage types of health insurance in the United States in 2019.

1.1 Objectives

1. To propose a linear multiclass classifier that yields high training accuracy.

2. To apply the proposed classification method to investigate significant factors influencing health insurance coverage.

1.2 Limitations

1. A nonlinear classifier is beyond the scope of the study. However, a suitable kernel function may be selected to solve a nonlinear classification problem.

2. An entire data is used to train a linear classifier. Hence, only training accuracy is measured.

3. The health insurance sample data only includes Americans. It was collected in 2020 to reflect health insurance coverage for entire calendar year 2019.

4. Despite its high training accuracy, the proposed classifier requires long training time and large space to store a branch-and-cut tree. Its approximation algorithm is not developed in this dissertation although mitigating both problems to some extent.

CHAPTER II

LITERATURE REVIEW

2.1 Health Insurance Coverage

A variety of statistical tools have long been used to study the factors related to health insurance coverage of multiple subpopulations across different countries. These analytical techniques include linear probability modeling (Cebula, 2006), probit regression analysis (Mulenga et al., 2021) and logistic regression analysis (Jin et al., 2016; Dolinsky and Caputo, 1997; Markowitz et al., 1991).

Generally, health insurance coverage across the U.S. states was positively associated with median family income, female labor force rate, the proportion of population aged 65 and over, and it was negatively linked with the percentages of household with husband absence and Hispanic household (Cebula, 2006). Psychological characteristics also greatly affected the influence of demographic factors among American women (Dolinsky and Caputo, 1997). After controlling for psychological variables, health status and employment were significant determinants only for married and unmarried women respectively. Income and education played important roles in both groups. Americans aged 18 to 24 with permanent, full-time employment were more likely to be insured than those with permanent, part-time employment (Markowitz et al., 1991). This trend became reverse specifically for the students. Low income, less education, rural residence, unmarried status, Hispanic ethnicity and Western residency were indicators of being uninsured in general.

Outside the United States, many research works on health insurance coverage have also been of interest. Income, education, health status and employment correlated with the coverage types among Chinese people aged 45 and over (Jin et al., 2016). Males dominated in both public and private health insurance. Migrants appeared to be covered by both rural and urban public insurance, private insurance or no insurance in comparison to local residents. Rural residents were more inclined to have public insurance coverage. Furthermore, private health insurance in Zambia tended to be purchased by males with service, skilled and unskilled occupations and rural residency as well as women in marital union and clerical duties (Mulenga et al., 2021).

2.2 Feature Selection

2.2.1 Decision Tree

Each parent node partitions a feature space by splitting a specific training variable into two intervals, left and right nodes (Scikit-learn, 2024). A splitting value is chosen to minimize the weighted average of the impurities of both child nodes by their number of training instances. This dissertation uses as an impurity measure the Gini index defined by the probability of a sample at a node being wrongly classified.

2.2.2 SelectKBest

The mutual information (Cover and Thomas, 2005) is a statistic for measuring relationship between two random variables or in practice two datasets.

Definiton 2.1. The *Kullback-Leibler distance* $D(f||g)$ between two densities f and g is defined by

$$D(f||g) = \int f \log \frac{f}{g}.$$

Definiton 2.2. The *mutual information* $I(X;Y)$ between two random variables with joint density $f(x,y)$ is defined as

$$I(X;Y) = D(f(x,y)||f(x)f(y)).$$

Two random variables share no mutual information, i.e. $I = 0$, only when both are independent. Suppose X is a training variable and Y a discrete target or class. A continuous feature requires an estimation of mutual information, for example by the k-nearest neighbor method (Ross, 2014), because its true probability remains practically unknown. Suppose the k-nearest neighbor of a training instance x^i of the same class has m_i instances of all classes and there are N_i out of N that share the same class with x^i. Compute

$$I_i = \psi(N) - \psi(N_i) + \psi(k) - \psi(m_i)$$

where the digamma function ψ is the logarithmic derivative of the gamma function. The mutual information $I(X;Y)$ is estimated by averaging I_i over all training instances.

Definiton 2.3. The *gamma function* Γ and *digamma function* ψ are defined on the set of positive real numbers by

$$\Gamma(z) = \int_0^\infty t^{z-1} e^{-t} dt$$

and

$$\psi(z) = \frac{d}{dz} \log \Gamma(z)$$

respectively.

CHAPTER III

RESEARCH METHODS

3.1 Overview

1. Propose a multiclass linear classifier which is able to predict continuous contributing factors, produces disconnected decision regions and provides minimum misclassification.

2. Extend the classifier when certain features of training data are allowed to be categorical.

3. Illustrate the use of the methods on the health insurance dataset.

4. Compare multiple facets of results with the use of a decision tree.

3.2 SSH Key Generation

The Secure Shell (SSH) protocol is employed for secure connection to a remote compute engine through one-way client authentication by a pair of asymmetric keys: private and public. SSH keys can be generated with the OpenSSH command `ssh-keygen` by using a native SSL/TLS library provided by an operating system: Secure Channel (Schannel) in Windows or OpenSSL in Linux. The latter keys are very specific to a currently active OpenSSL version especially when an alternative OpenSSL is manually built and installed. In this dissertation, the SSH keys are created on a local computer with the elliptic-curve Ed25519 algorithm (Bernstein et al., 2012), proven to be faster and more efficient than the RSA algorithm (Rivest et al., 1978).

```
cd ~/.ssh
ssh-keygen -f <output_keyfile> -C <comment> -t ed25519
```

A Google Cloud virtual machine requires the comment at the end of a public key file to be a Google username. Since the dissertation results are uploaded to a GitHub repository using SSH, an additional key pair specific to this purpose is suggested to tighten security. A host, a username and their private key must be included in the configuration file `~/.ssh/config` in the case of multiple key pairs.

```
Host <hostname>
    User <username>
    IdentityFile <private_keyfile>
```

Unlike Windows, Linux has the `.ssh` directory hidden, directly by the use of a dot character at the beginning, and partially inheritable POSIX access control list (ACL). A Linux parent directory does not reapply its new ACL to existing descendants, and it simply acts as during path resolution a gate with its execute permission.

The principle of least privilege (PoLP) should be applied to generated keys. Basically, only a key owner can read his/her private key, and the read-only permission on a public key is granted to everyone. In Linux, there are three POSIX permission levels: owner, group and other. Each level is represented by three permission bits: read (r), write(w) and execute (x). They are usually rewritten in base 10, ranging from 0 to 7. The `chmod` command is used to set all three levels of permission with three numerical digits.

```
chmod 400 <private_key>
chmod 444 <public_key>
```

In Windows, the command `icalcs` is used, and additional rights can be denied due to more fine-grained permission control as displayed in Table 3.1. An SSH key should be hidden and have no inherited NTFS permission. Its ownership is nontransferable. A SYSTEM account has no access to a private key. An Administrators group can only read, but neither change nor delete, its content, regular and extended attributes, and permissions. This set of access privileges is also applicable to a public key and granted to everyone.

```
icacls <key> /inheritancelevel:d
icacls <key> /grant <user>:F Administrators:F
attrib +h <key>
icacls <key> /remove <user> Administrators SYSTEM Everyone
icacls <key> /deny "<user>:(WD,AD,WA,WEA,DE,WDAC,WO)" `
    "Administrators:(WD,AD,WA,WEA,DE,WDAC,WO)"
icacls <key> /grant <user>:R Administrators:R
icacls <private_key> /deny SYSTEM:F
icacls <public_key> /deny "SYSTEM:(WD,AD,WA,WEA,DE,WDAC,WO)" `
    "Everyone:(WD,AD,WA,WEA,DE,WDAC,WO)"
icacls <public_key> /grant SYSTEM:R Everyone:R
```

Table 3.1: Example of advanced NTFS permissions in Windows

Permission	Description
WD	Write data or add file
AD	Append data or add subdirectory
WA	Write attributes
WEA	Write extended attributes
DE	Delete
WDAC	Write DAC (change permissions)
WD	Write data or add file

3.3 Remote Virtual Machine Setup

3.3.1 Specifications

All codes are executed on a Google Cloud compute engine with a 64-bit 8-vCPU 4-core CPU, 64 GB RAM and 250 GB SSD persistent disk running on Ubuntu Server 24.04 LTS. The instance locates in region `us-central1 (Iowa)` and zone `us-central1-f`. The standard provisioning model, although noticeably more high-priced than the spot counterpart, is chosen to prevent VM preemption primarily because the proposed classifier has exponential time complexity, thereby requiring exceptionally high CPU utilization. The network traffic is routed in a premium tier to provide low latency. A static external IPv4 address is reserved and assigned to the instance for remote connection.

3.3.2 SSH Key-Based Authentication

Password authentication should be disabled by uncommenting the following line in the SSH configuration file `/etc/ssh/sshd_config`.

```
PasswordAuthentication no
```

SSH authentication requires adding a public key of a local computer to the key file `/.ssh/authorized_keys`.

```
echo <public_keyfile> >> ~/.ssh/authorized_keys
```

3.3.3 Python Installation

Ubuntu Server 24.04 LTS is equipped with outdated Python 3.12.3. The installation of latest Python 3.13.0 at the current stage inevitably requires building from source. As opposed to Python 3.12, Python 3.13 experimentally supports multithreading without global interpreter lock (GIL). However, disabling GIL prevents the successful installation of `scikit-learn` package which is required to build a decision tree in Chapter 5. In this circumstance, the binary distribution, commonly known as wheel, of `scikit-learn` is unavailable. Its compilation by Rust and Cargo with the build system requirements specified in `pyproject.toml` also fails. Therefore, GIL remains as a default mechanism of mutual exclusion lock.

3.3.3.1 Introduction to Compilation in C

All Python source codes are written in C, and they require a C compiler such as GNU Compiler Collection (GCC) and Clang/Low Level Virtual Machine (LLVM). This dissertation chooses the first compiler. GCC 13 can be installed through the APT package manager.

```
sudo apt install build-essential
```

A newer version of GCC, currently GCC 14 release and GCC 15 experimental, can optionally be built from source by its previous version. The C/C++ compiler commands, including versions, and flags can be added to the environment variables `CC`, `CXX`, `CFLAGS` and `CXXFLAGS` respectively.

GNU Make is used as a build automation tool by reading instructions from `Makefile`. Parallelism is supported by utilizing multiple CPU threads with the `-j` or `--jobs` flag.

```
make -j<N>
make -j<N> install
```

The parameter `<N>` is the maximum allowable number of jobs executed in parallel which should not exceed the number of available CPU threads.

3.3.3.2 Basic Object Types

Python object structures are declared in the header file `Include/object.h`. A Python object is stored in memory, it has a C structure named `_object`, and it can be referenced as a `PyObject*` pointer. With GIL enabled by default, it declares a reference counter `ob_refcnt` of type `Py_ssize_t` and a pointer to the object type `*ob_type` of type `PyTypeObject`. When GIL is disabled by configuring Python with the `--disable-gil` option, a local reference counter is declared by `ob_ref_local` of type `uint32_t` is only adjusted by an owner thread, whereas a shared counterpart `ob_ref_shared` of type `Py_ssize_t` is adjusted by remaining threads. Its actual reference counter can be computed by merging both. When its reference counter is decremented to zero, it is deleted by a garbage collector (GC). If it only has a cyclic reference, a generational garbage collection is employed. A variable-size Python object can be cast further to `PyVarObject*` with an additional field `ob_size` of type `Py_ssize_t` which holds the number of its items.

```
#ifndef Py_GIL_DISABLED
struct _object {
    #if (defined(__GNUC__) || defined(__clang__)) \
    && !(defined __STDC_VERSION__ && __STDC_VERSION__ >= 201112L)
    // On C99 and older, anonymous union is a GCC and clang extension
    __extension__
    #endif
    #ifdef _MSC_VER
    // Ignore MSC warning C4201: "nonstandard extension used:
    // nameless struct/union"
    __pragma(warning(push))
    __pragma(warning(disable: 4201))
    #endif
    union {
        Py_ssize_t ob_refcnt;
        #if SIZEOF_VOID_P > 4
        PY_UINT32_T ob_refcnt_split[2];
        #endif
    };
    #ifdef _MSC_VER
    __pragma(warning(pop))
    #endif
```

```c
    PyTypeObject *ob_type;
};
#else
// Objects that are not owned by any thread use a thread id (tid) of zero.
// This includes both immortal objects and objects whose reference count
// fields have been merged.
#define _Py_UNOWNED_TID 0

// The shared reference count uses the two least-significant bits to store
// flags. The remaining bits are used to store the reference count.
#define _Py_REF_SHARED_SHIFT 2
#define _Py_REF_SHARED_FLAG_MASK 0x3

// The shared flags are initialized to zero.
#define _Py_REF_SHARED_INIT 0x0
#define _Py_REF_MAYBE_WEAKREF 0x1
#define _Py_REF_QUEUED 0x2
#define _Py_REF_MERGED 0x3

// Create a shared field from a refcnt and desired flags
#define _Py_REF_SHARED(refcnt, flags) (((refcnt) << _Py_REF_SHARED_SHIFT) + (flags))

struct _object {
    // ob_tid stores the thread id (or zero). It is also used by the GC and the
    // trashcan mechanism as a linked list pointer and by the GC to store the
    // computed "gc_refs" refcount.
    uintptr_t ob_tid;
    uint16_t _padding;
    PyMutex ob_mutex; // per-object lock
```

```
    uint8_t ob_gc_bits; // gc-related state
    uint32_t ob_ref_local; // local reference count
    Py_ssize_t ob_ref_shared; // shared (atomic) reference count
    PyTypeObject *ob_type;
};
#endif

/* Cast argument to PyObject* type. */
#define _PyObject_CAST(op) _Py_CAST(PyObject*, (op))

typedef struct {
    PyObject ob_base;
    Py_ssize_t ob_size; /* Number of items in variable part */
} PyVarObject;
```

3.3.3.3 String Interning

Python interns strings, which are immutable objects, of the same value mainly through the function `_PyUnicode_InternInPlace()` defined in the source file `Objects/unicodeobject.c` by retaining only one copy in memory. This reduces memory usage and speeds up certain operations, for example equality comparison. The reference to all interned strings is stored in the per-interpreter dictionary `interned` initialized during the first invocation. As opposed to a release build, a debug build denies with an assertion the addition of a process-global interned string into the existing dictionary to prevent the possibility of getting a duplicate.

```
static /* non-null */ PyObject*
intern_static(PyInterpreterState *interp, PyObject *s /* stolen */)
{
    // Note that this steals a reference to `s`, but in many cases
        that
    // stolen ref is returned, requiring no decref/incref.

    assert(s != NULL);
    assert(_PyUnicode_CHECK(s));
    assert(_PyUnicode_STATE(s).statically_allocated);
    assert(!PyUnicode_CHECK_INTERNED(s));
```

```
    #ifdef Py_DEBUG
    /* We must not add process-global interned string if there's
        already a
    * per-interpreter interned_dict, which might contain duplicates.
    */
    PyObject *interned = get_interned_dict(interp);
    assert(interned == NULL);
    #endif

    /* Look in the global cache first. */
    PyObject *r = (PyObject *)_Py_hashtable_get(INTERNED_STRINGS, s);
    /* We should only init each string once */
    assert(r == NULL);
    /* but just in case (for the non-debug build), handle this */
    if (r != NULL && r != s) {
        assert(_PyUnicode_STATE(r).interned ==
            SSTATE_INTERNED_IMMORTAL_STATIC);
        assert(_PyUnicode_CHECK(r));
        Py_DECREF(s);
        return Py_NewRef(r);
    }

    if (_Py_hashtable_set(INTERNED_STRINGS, s, s) < -1) {
        Py_FatalError("failed to intern static string");
    }

    _PyUnicode_STATE(s).interned = SSTATE_INTERNED_IMMORTAL_STATIC;
    return s;
}
```

Soon after Python 3.13.0 had been released, `JupyterLab` could not be launched in the debug build despite its successful installation. This problem can be fixed by commenting the following assert statement, though discouraged, and rebuilding the Python.

```
    //assert(interned == NULL);
```

This can also be done by using the `sed` command.

```
sed -i -e \
    's/assert(interned == NULL);/\/\/assert(interned == NULL);/g' \
    Objects/unicodeobject.c
```

However, the source code modification is not required for running the latest `JupyterLab`.

3.3.3.4 Configuration and Build

It is recommended to have three separate directories: source, build and install. In this dissertation, Python is built against OpenSSL whose runtime library directory `rpath` is automatically detected, and it respects the OpenSSL crypto policy `openssl.cnf` by overriding the default Python cipher list.

```
--with-openssl=<openssl_rootdir>
--with-openssl-rpath=auto
--with-ssl-default-suites=openssl
```

As opposed to the built-in Python, a static library (with `.a` extension) is built from source by default. This dissertation builds a dynamic library (with `.so` extension) by adding the `--enable-shared` flag to minimize disk footprint of several programs because Python 3.13.0 will intentionally be built as a new primary version, but inside a home directory without a symbolic link to the system Python binary located in `/usr/bin` shared by multiple native applications.

Although a release build, default in Python, is more optimized but harder to debug, this dissertation chooses the Python debug build by passing the `--with-pydebug` flag. The source codes are compiled to intermediate object codes in an attempt to reduce the code size and execution time. A linker produces shared libraries and executables from objects without duplicate definitions. Both compilation and linking are optimized by turning on the `--enable-optimizations` and `--with-lto` flags. C assertions are enabled in debug mode by default. Python can be compiled with profiling turned on by using the `--enable-profiling` flag. The GNU profiler `grpof` collects data during Python execution and outputs the file `gmon.out` in a current working directory. Based on this information, the code performance can be analyzed in terms of execution time and memory comsumption, and its bottleneck is identifiable. Nonetheless, this dissertation omits the profiling flag.

Python optimization, if specified, is profile-guided (PGO) based on collected data from sequential test runs. For the PGO generation task, Python by default uses the following arguments assigned to the environment variable `PROFILE_TASK`.

```
-m test --pgo --timeout=
```

The `-m` flag searches for all files matching a given pattern, in this case `test*` in the `Lib/test` subdirectory. The `--pgo` flag enables PGO training and selects 44 out of 478 test runs. Python 3.13 sets no timeout for an individual test, in contrast to Python 3.12 a default timeout of 20 minutes, and no longer ignores a test failure. Its build time is partly impacted by these test runs and can significantly improve by ignoring through the `-i` flag time-consuming tests which can be detected, for instance, by setting a custom timeout. This dissertation excludes the test for embedding APIs located at `Lib/test/test_embded.py` and sets a timeout of 5 minutes.

```
export PROFILE_TASK="-m test --pgo --timeout=300 -i test_embded"
```

No timeout error is raised, and all remaining 43 tests pass.

Furthermore, the `pyexpat` module can be built using an installed `expat` library by the `--with-system-expat` flag. DTrace, Valgrind and loadable extensions in the `_sqlite` extension module are supported by the `--with-dtrace`, `--with-valgrind` and `--enable-loadable-sqlite-extensions` flags. Address sanitizer (ASAN) and memory sanitizer (MSAN) are disabled by default. Certain flags requires additional dependencies. Their environment variables for C compiler and linker flags, required libraries, Python modules to be optionally built, and corresponding APT packages are given in Table 3.2.

Table 3.2: Python options for third-party dependencies

Environment Variables	Library	Module	APT Package
BZIP2_[LIBS|CFLAGS]	libbz2	bz2	libbz2-dev
CURSES_[LIBS|CFLAGS]	libncurses	curses	libncurses-dev
GDBM_[LIBS|CFLAGS]	gdbm		libgdbm-compat-dev
LIBB2_[LIBS|CFLAGS]	libb2	hashlib	libb2-dev
LIBEDIT_[LIBS|CFLAGS]	libedit	readline	libreadline-dev
LIBFFI_[LIBS|CFLAGS]	libffi	ctypes	libffi-dev
LIBMPDEC_[LIBS|CFLAGS]	libmpdec	decimal	
LIBLZMA_[LIBS|CFLAGS]	liblzma	lzma	liblzma-dev
LIBREADLINE_[LIBS|CFLAGS]	libreadline	readline	libreadline-dev
LIBSQLITE3_[LIBS|CFLAGS]	libsqlite3	sqlite3	libsqlite3-dev
LIBUUID_[LIBS|CFLAGS]	libuuid	uuid	uuid-dev
PANEL_[LIBS|CFLAGS]	libpanel	curses.panel	libpanel-dev

Table 3.2: Python options for third-party dependencies (continued)

Environment Variables	Library	Module	APT Package
TCLTK_[LIBS|CFLAGS]	TCLTK		tk-dev
ZLIB_[LIBS|CFLAGS]	libzlib	gzip	zlib1g-dev

After Python is completely installed in the destination directory, both source and build directories can be removed. The `bin` directory should be added to the `PATH` so that the executables are accessible from any location. The system environment variables `LD_LIBRARY_PATH` and `LDFLAGS` should include the `lib` directory so that the library code can be loaded into memory at runtime and compile time respectively. The recently built version must precede the system-wide version.

```
export PATH="<install_dir>/bin:$PATH"
export LD_LIBRARY_PATH="<install_dir>/lib:${LD_LIBRARY_PATH}"
export LDFLAGS="-L<install_dir>/lib $LDFLAGS"
```

This migration should be made to the Bash configuration file `~/.bashrc`. Depreciation warnings may be emitted during runtime, but they can be suppressed by setting the Python environment variable `PYTHONWARNINGS`.

```
export PYTHONWARNINGS="ignore::DeprecationWarning"
```

The changes are not applied until the configuration file is reread.

```
source ~/.bashrc
```

3.3.4 Backup to OCI Object Storage

3.3.4.1 Introduction to OCI

Oracle Cloud Infrastructure (OCI) basically has two logical concepts of organization management: tenancy and compartment. A *tenancy* is a root container for administering cloud resources. During the signup process, a parent tenancy is provisioned and tied to a specified, unchangeable home region which is `ap-singapore-1` in this dissertation. Multiple child tenancies can be created and managed by the parent tenancy. A *compartment* belongs to a tenancy, controls access to cloud resources, supports up to six levels, and brings clearer separation. It must be specified when a resource is created. A tenancy can be considered as a root compartment.

The OCI command line interface (CLI) can be installed by the `oci-cli` package in an isolated Python environment to prevent dependency conflicts. The `source` command is used to activate this environment. After the installation finishes, the executables including `oci` and its libraries are in the `bin` and `lib` directories. Only the first is additionally added to the `PATH` so that the `oci` command can be executed in the global environment, not limited to the virtual counterpart.

```
~$ python3 -m venv <env_dir>
~$ source <env_dir>/bin/activate
(env_dir)$ pip3 install oci-cli
(env_dir)$ deactivate
```

Before accessing an OCI resource or service, a basic OCI configuration must be made in an interactive mode from a terminal, for instance.

```
oci setup config
```

This can also be done from a custom configuration file by setting the environment variable `OCI_CLI_RC_FILE` to its full path. The file has two main components: section and key. A section except the default should be specified via the `--profile` option in the CLI.

```
[DEFAULT]
user=<user>
fingerprint=<fingerprint>
key_file=<key_file>
tenancy=<tenancy>
region=ap-singapore-1
```

3.3.4.2 OCI Object Storage

An object storage *namespace* serves as the top-level container for all buckets and objects, it is unique to a tenant, and it spans all compartments within a region. Although region-specific, its name remains the same across all regions. An *object* is any type of data along with its metadata stored in a logical container called *bucket* unique in a namespace. Object storage is highly scalable, cost-effective and structurally flat, compared to block and file storage. There are two default tiers. A *standard tier* has a higher cost and no retention period. In a low-cost *archive tier*, an object must be retained for at least 90 days, and restoration takes very long time to retrieve all data bytes. OCI Object storage supports auto-tiering, object versioning and multipart uploading which is greatly resilient for a very large object. Uncommitted of failed multipart uploads can be cleaned either manually or through a predefined lifecycle policy rule.

In this dissertation, only a full backup of scripts and results, not only due to its small size but also to avoid the possibility of a corrupted incremental or differential backup, is stored in OCI object storage. A total of 20 GB in all tenancies is always free, and no upgrade to a paid account is required. A bucket is created without auto-tiering and versioning. All buckets in a compartment can be listed along with their namespace.

```
oci os bucket list -c <compartment_id>
```

A backup is performed by a one-way synchronization, and each version is uniquely identified by an object prefix such as a timestamp. An object that exists in a destination but not in a source is deleted.

```
oci os object sync -ns <namespace> -bn <bucket> \
    --prefix <obj_prefix> --src-dir <src_dir> --delete
```

Furthermore, an object can be renamed and deleted where bulk deletion is also permitted.

```
oci os object rename -ns <namespace> -bn <bucket> \
    --name <obj_name> --new-name <obj_new_name>
oci os object delete -ns <namespace> -bn <bucket> \
    --name <obj_name>
oci os object bulk-delete -ns <namespace> -bn <bucket> \
    --prefix <obj_prefix>
```

3.4 GitHub Repository

The template GitHub repository for this dissertation is available at https://github.com/songkomkrit/phd-template. The basic Git commands are included in Table 3.3. The path to the Git global configuration file `.gitconfig` specific to a user is given by the environment variable `GIT_CONFIG_GLOBAL`. The username and the email address can be set up either by the `git config` command with the `--global` option or by editing the configuration file.

```
git config --global user.name <username>
git config --global user.email <email_address>
```

The following settings should appear in the file.

```
[user]
    name = <username>
    email = <email_address>
```

Table 3.3: Basic Git commands

Command	Description
`git clone`	Clean copy
`git pull`	Update with local changes kept
`git reset --hard`	Update with local changes discarded
`git clean -fdx`	Clean with untracked files and directories removed
`git push`	Remote update with local commits

The JSON-format metadata of both independent and dependent variables are at `Data/Original/metadata/meta-indep.json` and `Data/Original/metadata/meta-dep.json`. The health insurance in SAS7BDAT format is omitted, but its feather file of smaller size is already included in the directory `Data/Original/feature`. This dissertation further limits the number of participants and features to smaller size before fed to a classification model. Since data sampling is random, the sample is put in the directory `Samples/cplex`.

The box classifier proposed in Chapter 4 is located in the CPLEX Optimization Programming Language (OPL) project Projects/box where its input subdirectory contains a sample data including additional information and its output counterpart all relevant results such as splitting values and predicted class label per decision box. The model can be executed by the oplrun command and logged into file and on console by the tee command.

```
oplrun -p <project_dir> 2>&1 | tee <log_file>
```

The <project_dir> is Projects/box. Thanks to its comparative low-resource consumption, using the oplrun executable in a terminal is preferred to starting the CPLEX Studio IDE by executing the oplide command. The manual backup of the CPLEX engine log is stored in the directory Logs/box. The Python scripts for data preprocessing, decision tree building and decision box merging can be found in Scripts/Preprocessing/Python, Scripts/ML/Python and Scripts/Box/Python respectively. The directory and file tree structures can be printed in terminal by using the tree command, and they are saved to Structures/directory.txt and Structures/file.txt.

```
tree -d . > Structures/directory.txt
tree -f . > Structures/file.txt
```

There are currently 29 directories and 60 files. The directory structure is displayed in Figure 3.1.

The template repository is very minimal with merely output files generated by a CPLEX optimizer. Its main purpose is to allow users to generate a new repository with the same structure before further Python execution such as exploratory data analysis (EDA). The up-to-date repository based on the template with additional outputs included is available at https://github.com/songkomkrit/phd.

Figure 3.1: Directory tree structure of the template GitHub repository

```
phd-template
├─ Data
│  └─ Original
│     ├─ feather
│     └─ metadata
│        └─ full
├─ Logs
│  └─ box
├─ Projects
│  └─ box
│     ├─ input
│     ├─ log
│     ├─ output
│     └─ tmp
├─ Samples
│  └─ cplex
├─ Scripts
│  ├─ Box
│  │  └─ Python
│  │     └─ module
│  │        ├─ model
│  │        └─ operation
│  ├─ ML
│  │  └─ Python
│  └─ Preprocessing
│     └─ Python
│        ├─ cls
│        └─ module
└─ Structures
```

3.5 Health Insurance Dataset

3.5.1 Background

The 2020 U.S. Census Bureau's Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC) dataset will be used in the dissertation. Questions were asked for the information on a previous calendar year. Therefore, the person-level dataset provides the estimates of individual health insurance coverage for calendar year 2019.

An individual may simultaneously have different coverages. Private health insurance includes an employment-based plan and a direct-purchase plan. Public health insurance comprises Medicare, means-tested coverage (i.e., Medicaid, Peace Church Health Insurance or PCHIP and others), military healthcare (i.e., TRICARE formerly known as Civilian Health and Medical Program of the Uniformed Services or CHAMPUS, Civilian Health and Medical Program of the Department of Veterans Affairs or CHAMPVA and Veterans Affairs or VA) and the combination of Indian Health Service (IHS) and other coverages. Those who only have IHS are considered uninsured.

Since there are in total 10 subtypes of insurance coverage, quantitative data analysis may involve up to $2^{10} + 1 = 1{,}025$ possible classes. In fact, the maximum number of subtypes of an overall class can be determined by the total sum of the indicator variables of the first ten subtypes. Furthermore, the dataset has at least 150,000 records and 750 attributes which are mostly measured on nominal scales. In addition to their allocation and topcode flags, the dataset variables cover a broad spectrum of characteristics: demographics, work experience, income (i.e., earnings, other income, non-cash benefits and tax), poverty, health insurance (i.e., government, private, employment-based, direct-purchase, subsidized marketplace, unsubsidized marketplace, non-marketplace, Medicaid, other means-tested, PHCIP, Medicare, IHS, TRICARE, CHAMPVA, VA and employer-sponsored), health status and migration. They also include basic CPS items (i.e., labor force and earnings) and medical out-of-pocket (OOP) expenditures.

3.5.2 Scope of Study

Within existing conceptual frameworks, certain independent variables will be preselected in the dissertation before further investigation. A group of infant born after the calendar year is excluded in the analysis. The combination of three following coverages is merely considered: employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB). There are eight possible binary tuples (GRP, DIR, PUB) which are regrouped into five following classes in Table 3.4.

Table 3.4: Class codes of insurance coverage combination

Class	Code	Combination of insurance coverages		
		GRP	DIR	PUB
0	NNN	No	No	No
1	NNY	No	No	Yes
2	NY_	No	Yes	Yes
		No	Yes	No
3	YNN	Yes	No	No
4	Y1Y	Yes	No	Yes
		Yes	Yes	Yes
		Yes	Yes	No

3.5.3 Metadata

Metadata 3.1 and 3.2 contain related information on dependent and independent variables in JSON format with a variable symbol as a main key and all of the following as its informative value in dictionary format: label, universe, type (either continuous or categorical), topic, subtopic and possible values including NIU (not in universe).

Metadata 3.1: Dependent variables (data/original/metadata/meta-dep.json)

```
{
    "NOW_COV": {
        "label": "Currently covered by health insurance coverage",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Any health insurance coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_PUB": {
        "label": "Current public coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Public coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_PRIV": {
        "label": "Current private coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Private coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_GRP": {
        "label": "Any current employment-based coverage",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Employment-based coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_DIR": {
        "label": "Any current direct-purchase coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Direct-purchase coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_MCARE": {
        "label": "Current Medicare coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Medicare coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_MCAID": {
        "label": "Current Medicaid, PCHIP, or other means-tested coverage",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Medicaid or other means-tested coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_CAID": {
        "label": "Current Medicaid coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Medicaid coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_PCHIP": {
        "label": "Current PCHIP coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "PCHIP coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_OTHMT": {
        "label": "Current other means-tested coverage",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Other means-tested coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_MIL": {
        "label": "Any current TRICARE coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "TRICARE coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_CHAMPVA": {
        "label": "Current CHAMPVA coverage",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "CHAMPVA coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_VACARE": {
        "label": "Current VACARE coverage",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "VACARE coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    },
    "NOW_IHSFLG": {
        "label": "Current coverage through the Indian Health Service",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Dependent",
        "topic": "Health insurance",
        "subtopic": "Indian Health Service coverage",
        "values": {
            "1": "Yes",
            "2": "No"
        }
    }
}
```

Metadata 3.2: Independent variables (data/original/metadata/meta-indep.json)

```
{
    "A_AGE": {
        "label": "Age",
        "universe": "All Persons",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
```

```
            "00-79": "0-79 years of age",
            "80": "80-84 years of age",
            "85": "85+ years of age"
        }
    },
    "A_EXPRRP": {
        "label": "Expanded relationship code",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "1": "Reference person with relatives",
            "2": "Reference person without relatives",
            "3": "Husband",
            "4": "Wife",
            "5": "Own child",
            "7": "Grandchild",
            "8": "Parent",
            "9": "Brother/sister",
            "10": "Other relative",
            "11": "Foster child",
            "12": "Nonrelative with relatives",
            "13": "Partner/roommate",
            "14": "Nonrelative without relatives"
        }
    },
    "A_FAMTYP": {
        "label": "Family type",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
```

```
            "1": "Primary family",
            "2": "Nonfamily householder",
            "3": "Related subfamily",
            "4": "Unrelated subfamily",
            "5": "Secondary individual"
        }
    },
    "A_HGA": {
        "label": "Educational attainment",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "0": "Children",
            "31": "Less than 1st grade",
            "32": "1st,2nd,3rd,or 4th grade",
            "33": "5th or 6th grade",
            "34": "7th and 8th grade",
            "35": "9th grade",
            "36": "10th grade",
            "37": "11th grade",
            "38": "12th grade no diploma",
            "39": "High school graduate - high school diploma or equivalent",
            "40": "Some college but no degree",
            "41": "Associate degree in college - occupation/vocation program",
            "42": "Associate degree in college - academic program",
            "43": "Bachelor's degree (for example: BA,AB,BS)",
            "44": "Master's degree (for example: MA,MS,MENG,MED,MSW, MBA)",
            "45": "Professional school degree (for example: MD,DDS,DVM,LLB,JD)",
            "46": "Doctorate degree (for example: PHD,EDD)"
        }
```

```
    },
    "A_MARITL": {
        "label": "Marital status",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "1": "Married - civilian spouse present",
            "2": "Married - AF spouse present",
            "3": "Married - spouse absent (exc.separated)",
            "4": "Widowed",
            "5": "Divorced",
            "6": "Separated",
            "7": "Never married"
        }
    },
    "A_PFREL": {
        "label": "Primary family relationship",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "0": "Not in primary family",
            "1": "Husband",
            "2": "Wife",
            "3": "Own child",
            "4": "Other relative",
            "5": "Unmarried reference person"
        }
    },
    "A_SEX": {
        "label": "Sex",
```

```
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "1": "Male",
            "2": "Female"
        }
    },
    "P_STAT": {
        "label": "Status of person identifier",
        "universe": "All Persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "1": "Civilian 15+",
            "2": "Armed forces",
            "3": "Children 0-14"
        }
    },
    "PEAFEVER": {
        "label": "Did you ever serve on active duty in the U.S. Armed Forces?",
        "universe": "A_AGE greater than or equal to 17",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
```

```
    },
    "PEDISDRS": {
        "label": "Does...have difficulty dressing or bathing?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEDISEAR": {
        "label": "Is...deaf or does ...have serious difficulty hearing?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEDISEYE": {
        "label": "Is...blind or does...have serious difficulty seeing even when wearing glasses?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
```

```
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEDISOUT": {
        "label": "Because of a physical, mental, or emotional condition, does...have difficulty doing errands along such as visiting a doctor's office or shopping?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEDISPHY": {
        "label": "Does...have serious difficulty Walking or climbing stairs?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEDISREM": {
```

```
        "label": "Because of a physical, mental, or emotional condition, does...have serious difficulty concentrating, remembering, or making decisions?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PRDISFLG": {
        "label": "Does this person have any of these disability conditions?",
        "universe": "PRPERTYP = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "-1": "Not in universe",
            "1": "Yes",
            "2": "No"
        }
    },
    "PRCITSHP": {
        "label": "Citizenship group",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
```

```
            "1": "Native, born in US",
            "2": "Native, born in PR or US outlying area",
            "3": "Native, born abroad of US parent(s)",
            "4": "Foreign born, US cit by naturalization",
            "5": "Foreign born, not a US citizen"
        }
    },
    "PRDTRACE": {
        "label": "Race",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Demographics",
        "subtopic": "Individual characteristics",
        "values": {
            "1": "White only",
            "2": "Black only",
            "3": "American Indian, Alaskan Native only (AI)",
            "4": "Asian only",
            "5": "Hawaiian/Pacific Islander only (HP)",
            "6": "White-Black",
            "7": "White-AI",
            "8": "White-Asian",
            "9": "White-HP",
            "10": "Black-AI",
            "11": "Black-Asian",
            "12": "Black-HP",
            "13": "AI-Asian",
            "14": "AI-HP",
            "15": "Asian-HP",
            "16": "White-Black-AI",
            "17": "White-Black-Asian",
            "18": "White-Black-HP",
            "19": "White-AI-Asian",
            "20": "White-AI-HP",
            "21": "White-Asian-HP",
```

```
            "22": "Black-AI-Asian",
            "23": "White-Black-AI-Asian",
            "24": "White-AI-Asian-HP",
            "25": "Other 3 race comb.",
            "26": "Other 4 or 5 race comb."
        }
    },
    "A_MJIND": {
        "label": "Major industry code",
        "universe": "A_CLSWKR = 1-7",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited labor force items",
        "values": {
            "0": "Not in universe, or children",
            "1": "Agriculture, forestry,fishing, and hunting",
            "2": "Mining",
            "3": "Construction",
            "4": "Manufacturing",
            "5": "Wholesale and retail trade",
            "6": "Transportation and utilities",
            "7": "Information",
            "8": "Financial activities",
            "9": "Professional and business services",
            "10": "Educational and health services",
            "11": "Leisure and hospitality",
            "12": "Other services",
            "13": "Public administration",
            "14": "Armed forces"
        }
    },
    "A_MJOCC": {
        "label": "Major occupation recode",
        "universe": "A_CLSWKR = 1-7",
        "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited labor force items",
        "values": {
            "0": "Not in universe or children",
            "1": "Management, business, and financial occupations",
            "2": "Professional and related occupations",
            "3": "Service occupations",
            "4": "Sales and related occupations",
            "5": "Office and administrative support occupations",
            "6": "Farming, fishing, and forestry occupations",
            "7": "Construction and extraction occupations",
            "8": "Installation, maintenance, and repair occupations",
            "9": "Production occupations",
            "10": "Transportation and material moving occupations",
            "11": "Armed forces"
        }
    },
    "PEIO1COW": {
        "label": "Individual class of worker on first job",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited labor force items",
        "values": {
            "0": "NIU",
            "1": "Government-federal",
            "2": "Government-state",
            "3": "Government - local",
            "4": "Private, for profit",
            "5": "Private, nonprofit",
            "6": "Self-employed, incorporated",
            "7": "Self-employed, unincorporated",
            "8": "Without pay"
        }
```

```
    },
    "PRDISC": {
        "label": "Discouraged worker recode",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited labor force items",
        "values": {
            "0": "NIU",
            "1": "Discouraged worker",
            "2": "Conditionally interested",
            "3": "Not available"
        }
    },
    "PRUNTYPE": {
        "label": "Individual class of worker on first job",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited labor force items",
        "values": {
            "0": "NIU",
            "1": "Job loser/on layoff",
            "2": "Other job loser",
            "3": "Temporary job ended",
            "4": "Job leaver",
            "5": "Re-entrant",
            "6": "New-entrant"
        }
    },
    "A_GRSWK": {
```

```
        "label": "How much does ... usually earn per week at this job before deductions , subject to topcoding, the higher of either the amount of item 25a times Item 25c or the actual item 25d entry will be present",
        "universe": "PRERELG=1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited earnings items",
        "values": {
            "0": "Not in universe or children or armed forces",
            "0001-2885": "Dollar amount"
        }
    },
    "A_HRLYWK": {
        "label": "Is ... paid by the hour on this job?",
        "universe": "PRERELG=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited earnings items",
        "values": {
            "0": "Not in universe or children and armed forces",
            "1": "Yes",
            "2": "No"
        }
    },
    "A_HRSPAY": {
        "label": "How much does ... earn per hour?",
        "universe": "A_HRLYWK=1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited earnings items",
        "values": {
            "0": "Not in universe or children or armed forces",
```

```
            "0001-9999": "Entry (2 implied decimal places)"
        }
    },
    "PRERELG": {
        "label": "Earnings eligibility flag",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Edited earnings items",
        "values": {
            "0": "Not earnings eligible",
            "1": "Earnings eligible"
        }
    },
    "A_CIVLF": {
        "label": "Civilian labor force",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in universe or children and Armed Forces",
            "1": "In universe"
        }
    },
    "A_CLSWKR": {
        "label": "Class of worker",
        "universe": "PEMLR=1-3 or (PEMLR=4-7 and person worked in the last 12 months)",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
```

```
            "0": "Not in universe or children and armed forces",
            "1": "Private",
            "2": "Federal government",
            "3": "State government",
            "4": "Local government",
            "5": "Self-employed-incorporated",
            "6": "Self-employed-not incorporated",
            "7": "Without pay",
            "8": "Never worked"
        }
    },
    "A_EXPLF": {
        "label": "Experienced labor force employment status",
        "universe": "PEMLR=1-4",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in experienced labor force",
            "1": "Employed",
            "2": "Unemployed"
        }
    },
    "A_LFSR": {
        "label": "Labor force status recode",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Children or Armed Forces",
            "1": "Working",
            "2": "With job, not at work",
            "3": "Unemployed, looking for work",
```

```
            "4": "Unemployed, on layoff",
            "7": "Nilf"
        }
    },
    "A_UNCOV": {
        "label": "On this job, is ... covered by a union or employee association contract?",
        "universe": "A_UNMEM=2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in universe or children and armed forces",
            "1": "Yes",
            "2": "No"
        }
    },
    "A_UNMEM": {
        "label": "On this job, is ... a member of a labor union or of an employee association similar to a union?",
        "universe": "PRERELG=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in universe or children and armed forces",
            "1": "Yes",
            "2": "No"
        }
    },
    "A_UNTYPE": {
        "label": "Reason for unemployment",
        "universe": "A_LFSR=3 or 4",
        "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in universe or children and Armed Forces",
            "1": "Job loser - on layoff",
            "2": "Other job loser",
            "3": "Job leaver",
            "4": "Re-entrant",
            "5": "New entrant"
        }
    },
    "A_USLHRS": {
        "label": "How many hrs per week does ... usually work at this job?",
        "universe": "All persons",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "-4": "Hours vary",
            "-1": "Not in universe",
            "00": "None, no hours",
            "01-99": "Entry"
        }
    },
    "A_WKSCH": {
        "label": "Labor force by time worked or lost",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Not in universe",
```

```
            "1": "At work",
            "2": "With job, not at work",
            "3": "Unemployed, seeks FT",
            "4": "Unemployed, seeks PT"
        }
    },
    "A_WKSLK": {
        "label": "Duration of unemployment",
        "universe": "PEMLR=3 or 4",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "000": "NIU, Children or Armed Forces",
            "001-999": "Entry"
        }
    },
    "A_WKSTAT": {
        "label": "Full/part-time status",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "Children or Armed Forces",
            "1": "Not in labor force",
            "2": "Full-time schedules",
            "3": "Part-time for economic reasons, usually FT",
            "4": "Part-time for non-economic reasons, usually PT",
            "5": "Part-time for economic reasons, usually PT",
            "6": "Unemployed FT",
            "7": "Unemployed PT"
        }
    },
```

```
"PEHRUSLT": {
    "label": "Hours usually worked last week",
    "universe": "All persons",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Basic CPS items",
    "subtopic": "Labor force person recodes",
    "values": {
        "-4": "Hours vary",
        "-1": "NIU - adult civilian",
        "000": "NIU - children or Armed Forces or no hours",
        "1-198": "# of hours"
    }
},
"PEMLR": {
    "label": "Major labor force recode",
    "universe": "All persons",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Basic CPS items",
    "subtopic": "Labor force person recodes",
    "values": {
        "0": "NIU",
        "1": "Employed - at work",
        "2": "Employed - absent",
        "3": "Unemployed - on layoff",
        "4": "Unemployed - looking",
        "5": "Not in labor force - retired",
        "6": "Not in labor force - disabled",
        "7": "Not in labor force - other"
    }
},
"PRCOW1": {
    "label": "Class of worker recode-job 1",
    "universe": "All persons",
    "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "NIU",
            "1": "Federal govt",
            "2": "State govt",
            "3": "Local govt",
            "4": "Private (incl. self-employed incorp.)",
            "5": "Self-employed, unincorp.",
            "6": "Without pay"
        }
    },
    "PRPTREA": {
        "label": "Detailed reason for part-time",
        "universe": "Part time workers",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "NIU",
            "1": "Usually FT - slack work/business conditions",
            "2": "Usually FT - seasonal work",
            "3": "Usually FT - job started/ended during week",
            "4": "Usually FT - vacation/personal day",
            "5": "Usually FT - own illness/injury/medical appt",
            "6": "Usually FT - holiday (religious or legal)",
            "7": "Usually FT - child care problems",
            "8": "Usually FT - other fam/pers obligations",
            "9": "Usually FT - labor dispute",
            "10": "Usually FT - weather affected job",
            "11": "Usually FT - school/training",
            "12": "Usually FT - civic/military duty",
            "13": "Usually FT - other reason",
            "14": "Usually PT - slack work/business conditions",
```

```
            "15": "Usually PT - PT could only find PT work",
            "16": "Usually PT - seasonal work",
            "17": "Usually PT - child care problems",
            "18": "Usually PT - other fam/pers obligations",
            "19": "Usually PT - health/medical limitations",
            "20": "Usually PT - school/training",
            "21": "Usually PT - retired/social security limit on earnings",
            "22": "Usually PT - workweek<35 hours",
            "23": "Usually PT - other"
        }
    },
    "PRWKSTAT": {
        "label": "Full/part-time work status",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Basic CPS items",
        "subtopic": "Labor force person recodes",
        "values": {
            "0": "NIU",
            "1": "Not in labor force",
            "2": "FT hours (35+), usually FT",
            "3": "PT for economic reasons, usually FT",
            "4": "PT for non-economic reasons, usually FT",
            "5": "Not at work, usually FT",
            "6": "PT hrs, usually PT for economic reasons",
            "7": "PT hrs, usually PT for non-economic",
            "8": "FT hours, usually PT for economic reasons",
            "9": "FT hours, usually PT for non-economic reasons",
            "10": "Not at work, usually part-time",
            "11": "Unemployed FT",
            "12": "Unemployed PT"
        }
    },
    "CLWK": {
        "label": "Longest job class of worker (recode)",
```

```
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Private",
            "2": "Government",
            "3": "Self-employed",
            "4": "Without pay",
            "5": "Never worked"
        }
    },
    "EARNER": {
        "label": "Earner status recode",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Earner",
            "2": "Nonearner"
        }
    },
    "HRSWK": {
        "label": "In the weeks that ... worked how may hours did ... usually work per week?",
        "universe": "WKSWORK > 0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
```

```
            "0": "Niu",
            "1": "1 hour",
            "2-98": "2-98 hours",
            "99": "99 hours plus"
        }
    },
    "LJCW": {
        "label": "Longest job class of worker",
        "universe": "WKSWORK > 0",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Private",
            "2": "Federal",
            "3": "State",
            "4": "Local",
            "5": "Self employed incorporated, yes",
            "6": "Self employed incorporated, no or farm",
            "7": "Without pay"
        }
    },
    "NWLKWK": {
        "label": "How may different weeks was ... looking for work or on
            layoff?",
        "universe": "NWLOOK = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "1 week",
            "2-51": "2-51 weeks",
```

```
            "52": "52 weeks"
        }
    },
    "NWLOOK": {
        "label": "Even though ... did not work in 20.. did spend and time trying to find a job or on layoff?",
        "universe": "WORKYN = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PHMEMPRS": {
        "label": "For how many employers did ... work in 20..? if more than one at same time, only count it as one employer",
        "universe": "WKSWORK > 0",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "One employer",
            "2": "Two employers",
            "3": "3 or more employers"
        }
    },
    "RSNNOTW": {
        "label": "What was the main reason ... did not work in 20..?",
        "universe": "WORKYN = 2",
        "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Ill or disabled",
            "2": "Retired",
            "3": "Taking care of home",
            "4": "Going to school",
            "5": "Could not find work",
            "6": "Other"
        }
    },
    "WECLW": {
        "label": "Longest job class of worker (persons 15+)",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Not in universe",
            "1": "Agriculture (Wage and salary)",
            "2": "Agriculture (Self-employed)",
            "3": "Agriculture (Unpaid)",
            "4": "Nonagriculture (Private household",
            "5": "Nonagriculture (Other private)",
            "6": "Nonagriculture (Government)",
            "7": "Nonagriculture (Self-employed)",
            "8": "Nonagriculture (Unpaid)",
            "9": "Nonagriculture (Never worked)"
        }
    },
    "WEWKRS": {
        "label": "Weeks worked recode",
        "universe": "All persons aged 15+",
```

```
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Full-year worker (Full time)",
            "2": "Full-year worker (Part time)",
            "3": "Part-year worker (Full time)",
            "4": "Part-year worker (Part time)",
            "5": "Part-year worker (Nonworker)"
        }
    },
    "WKSWORK": {
        "label": "During 20.. in how many weeks did ... work even for a few hours? (include paid vacation and sick leave as work)",
        "universe": "Persons 15+ with WORKYN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "1 week",
            "2-51": "2-51 weeks",
            "52": "52 weeks"
        }
    },
    "WORKYN": {
        "label": "Did ... work at a job or business at any time during 20..?",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
```

```
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "WRK_CK": {
        "label": "Worked last year recode, including temporary and part-time",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "WTEMP": {
        "label": "Did ... do any temporary, part-time, or seasonal work even for a few days during 20..?",
        "universe": "WORKYN = 2",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Work experience",
        "subtopic": "General",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "ERN_OTR": {
        "label": "Wage and salary money earned from other work, Y/N",
```

```
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "ERN_SRCE": {
        "label": "Source of earnings from longest job",
        "universe": "ERN_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "Niu",
            "1": "Wage and salary",
            "2": "Self employment",
            "3": "Farm self employment",
            "4": "Without pay"
        }
    },
    "ERN_VAL": {
        "label": "How much did ... earn from this employer before
            deductions in 20..? what was ... net earnings from this
            business/ farm after expenses during 20..?",
        "universe": "ERN_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
```

```
            "0": "None or Niu",
            "-9,999 - 9,999,999": "Wages & self-employment"
        }
    },
    "ERN_YN": {
        "label": "Earnings from employer or net earnings from business/farm after expenses from longest job during 20.. ?",
        "universe": "WORKYN=1 or WTEMP=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "FRM_VAL": {
        "label": "Amount of farm self-employment earnings from secondary source",
        "universe": "FRMOTR = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or Niu",
            "-999999-999999": "Farm self employment"
        }
    },
    "FRMOTR": {
        "label": "Receiving farm self-employment from secondary source",
        "universe": "ERN_OTR = 1",
        "type": "Categorical",
        "role": "Independent",
```

```
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "FRSE_VAL": {
        "label": "Total amount of farm self-employment earnings",
        "universe": "ERN_YN=1 or FRMOTR=1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or Niu;",
            "-999999-999999": "Farm self employment"
        }
    },
    "FRSE_YN": {
        "label": "Receiving any farm self-employment",
        "universe": "ERN_YN=1 or FRMOTR=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEARNVAL": {
        "label": "Total persons earnings",
        "universe": "All persons aged 15+",
```

```
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None;",
            "negative amt": "Income (loss);",
            "positive amt": "Income"
        }
    },
    "SE_VAL": {
        "label": "Amount of own business self-employment earnings from
            secondary source",
        "universe": "SEOTR = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or niu;",
            "-99999-999999": "Own business self employment"
        }
    },
    "SEMP_VAL": {
        "label": "Total own business self-employment earnings (combined
            amounts in ern-val, if ern-srce=2, and se-val)",
        "universe": "ERN_YN=1 or SEOTR=1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or niu;",
            "-99999-999999": "Own business self employment"
        }
    },
```

```
"SEMP_YN": {
    "label": "Receiving own business self-employment, y/n",
    "universe": "ERN_YN=1 or SEOTR=1",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Earnings",
    "values": {
        "0": "Niu",
        "1": "Yes",
        "2": "No"
    }
},
"SEOTR": {
    "label": "Receiving own business self-employment, y/n",
    "universe": "ERN_YN=1 or SEOTR=1",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Earnings",
    "values": {
        "0": "Niu",
        "1": "Yes",
        "2": "No"
    }
},
"WAGEOTR": {
    "label": "Receiving wage and salary earnings from other employers, y/n",
    "universe": "ERN_OTR = 1",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Earnings",
    "values": {
        "0": "Niu",
```

```
            "1": "Yes",
            "2": "No"
        }
    },
    "WS_VAL": {
        "label": "Amount of wage and salary earnings from other employers",
        "universe": "ERN_OTR = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or niu;",
            "1-9999999": "Wage and salary"
        }
    },
    "WSAL_VAL": {
        "label": "Total wage and salary earnings (combined amounts in ern-val, if ern-srce=1, and ws-val)",
        "universe": "ERN_YN=1 or WAGEOTR=1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
        "values": {
            "0": "None or niu;",
            "1-9999999": "Wage and salary"
        }
    },
    "WSAL_YN": {
        "label": "Receiving wage and salary earnings",
        "universe": "ERN_YN=1 or WAGEOTR=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Earnings",
```

```
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "ANN_VAL": {
        "label": "Retirement income, annuities amount",
        "universe": "ANN_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "-1": "Niu",
            "0-999999": "Dollar amount"
        }
    },
    "ANN_YN": {
        "label": "Retirement income, annuities, y/n",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "CAP_VAL": {
        "label": "Capital gains value",
        "universe": "CAP_YN = 1",
        "type": "Continuous",
        "role": "Independent",
```

```
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Captial gains amount"
        }
    },
    "CAP_YN": {
        "label": "Yes/no answer to 'Did you receive capital gain from your shares of stock or mutual fund?'",
        "universe": "DIV_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "DBTN_VAL": {
        "label": "Total amount of retirement distributions received (dst_val1 + dst_val2)",
        "universe": "DST_VAL1>0 OR DST_VAL2>0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-9999999": "Dollar amount"
        }
    },
    "DIS_SC1": {
        "label": "What was the source of disability income?",
```

```
        "universe": "DIS_YN=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Worker's compensation",
            "2": "Company or union disability",
            "3": "Federal government disability",
            "4": "Us military retirement disability",
            "5": "State or local gov't employee disability",
            "6": "Us railroad retirement disability",
            "7": "Accident or disability insurance",
            "8": "Blacklung miners disability",
            "9": "State temporary sickness",
            "10": "Other or don't know"
        }
    },
    "DIS_SC2": {
        "label": "What was the source of disability income?",
        "universe": "DIS_YN=1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Worker's compensation",
            "2": "Company or union disability",
            "3": "Federal government disability",
            "4": "Us military retirement disability",
            "5": "State or local gov't employee disability",
            "6": "Us railroad retirement disability",
            "7": "Accident or disability insurance",
            "8": "Blacklung miners disability",
```

```
            "9": "State temporary sickness",
            "10": "Other or don't know"
        }
    },
    "DIS_VAL1": {
        "label": "How much did ... receive (source type) during 20.. ?",
        "universe": "DIS_SC1>0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Disability income"
        }
    },
    "DIS_VAL2": {
        "label": "How much did ... receive (source type) during 20.. ?",
        "universe": "DIS_SC2>0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Disability income"
        }
    },
    "DIS_YN": {
        "label": "Other than social security did ... receive any income in
            20.. as a result of health problems?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
```

```
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "DIV_VAL": {
        "label": "How much did ... receive in dividends from stocks or
            mutual funds during 20.. ?",
        "universe": "DIV_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Dividends"
        }
    },
    "DIV_YN": {
        "label": "Did ... receive dividends?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "DSAB_VAL": {
        "label": "Total amount of disability income received, combined
            amounts in edited sources one and two",
        "universe": "DIS_VAL1>0 OR DIS_VAL2>0",
```

```
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Disability income"
        }
    },
    "DST_SC1": {
        "label": "Retirement income, distribution source 1",
        "universe": "DST_VAL1 > 0 and a_age >= 58",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "401k account",
            "2": "403b account",
            "3": "Roth ira",
            "4": "Regular ira",
            "5": "Keogh plan",
            "6": "Sep plan (simplified employee pension)",
            "7": "Other type of retirement account"
        }
    },
    "DST_SC1_YNG": {
        "label": "Retriement Distribution source 1, person under age 58",
        "universe": "DST_YN_YNG = 1 and a_age < 58",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
```

```
            "1": "401k account",
            "2": "403b account",
            "3": "Roth ira",
            "4": "Regular ira",
            "5": "Keogh plan",
            "6": "Sep plan (simplified employee pension)",
            "7": "Other type of retirement account"
        }
    },
    "DST_SC2": {
        "label": "Retirement income, distribution source 2",
        "universe": "DST_VAL2 > 0 and a_age >= 58",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "401k account",
            "2": "403b account",
            "3": "Roth ira",
            "4": "Regular ira",
            "5": "Keogh plan",
            "6": "Sep plan (simplified employee pension)",
            "7": "Other type of retirement account"
        }
    },
    "DST_SC2_YNG": {
        "label": "Retriement Distribution source 2, person under age 58",
        "universe": "DST_VAL_YNG > 0 and a_age < 58",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
```

```
        "1": "401k account",
        "2": "403b account",
        "3": "Roth ira",
        "4": "Regular ira",
        "5": "Keogh plan",
        "6": "Sep plan (simplified employee pension)",
        "7": "Other type of retirement account"
    }
},
"DST_VAL1": {
    "label": "Retirement income amount, distribution source 1",
    "universe": "DST_SC1 = 1",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Other income",
    "values": {
        "0": "None or niu",
        "1- 999,999": "Amount withdrawn or distributed"
    }
},
"DST_VAL1_YNG": {
    "label": "Retriement Distribution amount 1, under age 58",
    "universe": "DST_SC1_YNG = 1",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Other income",
    "values": {
        "0": "None or niu",
        "1- 999,999": "Amount withdrawn or distributed"
    }
},
"DST_VAL2": {
    "label": "Retirement income amount, distribution source 2",
    "universe": "DST_SC2 = 1",
```

```
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1- 999,999": "Amount withdrawn or distributed"
        }
    },
    "DST_VAL2_YNG": {
        "label": "Retriement Distribution amount 2, under age 58",
        "universe": "DST_SC2_YNG = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1- 999,999": "Amount withdrawn or distributed"
        }
    },
    "DST_YN": {
        "label": "Retirement income distribution y/n",
        "universe": "Persons aged 58 and over (a_age >= 58)",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "DST_YN_YNG": {
        "label": "Retriement Distribution Recipiency, person under age 58",
```

```
        "universe": "Persons under age 58 (a_age < 58)",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "ED_VAL": {
        "label": "Total amount of educational assistance received (combined amounts in pell grant and other educational) assistance during 20.. ?",
        "universe": "ED_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1- 99,999": "Dollar amount"
        }
    },
    "ED_YN": {
        "label": "Did ... receive educational assistance?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
```

```
        }
    },
    "FIN_VAL": {
        "label": "How much did ... receive in financial assistance income during 20.. ?",
        "universe": "FIN_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Financial assistance"
        }
    },
    "FIN_YN": {
        "label": "Did ... receive financial assistance?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "INT_VAL": {
        "label": "Edited total combined interest income",
        "universe": "INT_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
```

```
            "0": "None or niu;",
            "1- 999,999": "Dollar amount"
        }
    },
    "INT_YN": {
        "label": "Edited total combined interest income, y/n",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "OED_TYP1": {
        "label": "Source 1 other than gi bill received (OED_TYP1- source of other government assistance)",
        "universe": "ED_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "OED_TYP2": {
        "label": "Source 2 other than gi bill received (OED_TYP2- scholarships, grants etc. from the school)",
        "universe": "ED_YN = 1",
        "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "OED_TYP3": {
        "label": "Source other than gi bill received (OED_TYP3- other assistance (employers friends, etc.)",
        "universe": "ED_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "OI_OFF": {
        "label": "Other income sources",
        "universe": "OI_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Social security",
            "2": "Private pensions",
            "3": "Afdc",
            "4": "Other public assistance",
```

```
            "5": "Interest",
            "6": "Dividends",
            "7": "Rents or royalties",
            "8": "Estates or trusts",
            "9": "State disability payments (worker's comp)",
            "10": "Disability payments (own insurance)",
            "11": "Unemployment compensation",
            "12": "Strike benefits",
            "13": "Annuities or paid up insurance policies",
            "14": "Not income",
            "15": "Longest job",
            "16": "Wages or salary",
            "17": "Nonfarm self-employment",
            "18": "Farm self-employment",
            "19": "Anything else",
            "20": "Alimony"
        }
    },
    "OI_VAL": {
        "label": "How much did ... receive in other incomes",
        "universe": "OI_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Other income"
        }
    },
    "OI_YN": {
        "label": "Did ... receive cash income not already covered from any
            other source?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
```

```
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PEN_SC1": {
        "label": "Retirement income, pension source 1",
        "universe": "PEN_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Company pension",
            "2": "Union pension",
            "3": "Federal government pension",
            "4": "State government pension",
            "5": "Local government pension",
            "6": "Us military pension",
            "7": "Us railroad retirement",
            "8": "Other"
        }
    },
    "PEN_SC2": {
        "label": "Retirement income, pension source 2",
        "universe": "PEN_VAL2 > 0",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
```

```
            "1": "Company pension",
            "2": "Union pension",
            "3": "Federal government pension",
            "4": "State government pension",
            "5": "Local government pension",
            "6": "Us military pension",
            "7": "Us railroad retirement",
            "8": "Other"
        }
    },
    "PEN_VAL1": {
        "label": "Retirement income amount, pension source 1",
        "universe": "PEN_SC1 > 0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999,999": "Pension income"
        }
    },
    "PEN_VAL2": {
        "label": "Retirement income amount, pension source 2",
        "universe": "PEN_SC2 > 0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999,999": "Pension income"
        }
    },
    "PEN_YN": {
        "label": "Retirement income, pension y/n",
```

```
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PNSN_VAL": {
        "label": "Total combined amount of pension income received from all pension sources",
        "universe": "PEN_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-9,999,999": "Retirement income"
        }
    },
    "PTOTVAL": {
        "label": "Total persons income",
        "universe": "All Persons aged 15+",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None",
            "negative amt": "Income (loss)",
            "positive amt": "Income"
        }
```

```
    },
    "RESNSS1": {
        "label": "What were the reasons (you/name) (was/were) getting Social Security Income last year?",
        "universe": "SS_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Retired",
            "2": "Disabled (adult or child)",
            "3": "Widowed",
            "4": "Spouse",
            "5": "Surviving child",
            "6": "Dependent child",
            "7": "On behalf of surviving, dependent, or disabled child(ren)",
            "8": "Other (adult or child)"
        }
    },
    "RESNSS2": {
        "label": "What were the reasons (you/name) (was/were) getting Social Security Income last year?",
        "universe": "SS_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Retired",
            "2": "Disabled (adult or child)",
            "3": "Widowed",
            "4": "Spouse",
```

```
            "5": "Surviving child",
            "6": "Dependent child",
            "7": "On behalf of surviving, dependent, or disabled child(ren)",
            "8": "Other (adult or child)"
        }
    },
    "RESNSSI1": {
        "label": "What were the reasons (you/name) (was/were) getting Supplemental Security Income last year?",
        "universe": "SSI_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Disabled (adult or child)",
            "2": "Blind (adult or child)",
            "3": "On behalf of a disabled child",
            "4": "On behalf of a blind child",
            "5": "Other (adult or child)"
        }
    },
    "RESNSSI2": {
        "label": "What were the reasons (you/name) (was/were) getting Supplemental Security Income last year?",
        "universe": "SSI_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Disabled (adult or child)",
            "2": "Blind (adult or child)",
```

```
            "3": "On behalf of a disabled child",
            "4": "On behalf of a blind child",
            "5": "Other (adult or child)"
        }
    },
    "RETCB_VAL": {
        "label": "Retirement contributiion, amount",
        "universe": "RETCB_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-99999": "Amount contributed"
        }
    },
    "RETCB_YN": {
        "label": "Retirement contribution, y/n",
        "universe": "All people 15 years and over",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "RINT_SC1": {
        "label": "Interest income, retirement source 1",
        "universe": "RINT_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
```

```
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "401k account",
            "2": "403b account",
            "3": "Roth ira",
            "4": "Regular ira",
            "5": "Keogh plan",
            "6": "Sep plan (simplified employee pension)",
            "7": "Other type of retirement account"
        }
    },
    "RINT_SC2": {
        "label": "Interest income, retirement source 2",
        "universe": "RINT_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "401k account",
            "2": "403b account",
            "3": "Roth ira",
            "4": "Regular ira",
            "5": "Keogh plan",
            "6": "Sep plan (simplified employee pension)",
            "7": "Other type of retirement account"
        }
    },
    "RINT_VAL1": {
        "label": "Interest income amt, retirement source 1",
        "universe": "RINT_SC1 > 0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
```

```
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Ret interest income"
        }
    },
    "RINT_VAL2": {
        "label": "Interest income amt, retirement source 2",
        "universe": "RINT_SC2 > 0",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Ret interest income"
        }
    },
    "RINT_YN": {
        "label": "Interest income - retirement, y/n",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "RNT_VAL": {
        "label": "How much did ... receive in income from rent after expenses during 20..?",
        "universe": "RNT_YN = 1",
        "type": "Continuous",
```

```
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "-9999-999999": "Rental income"
        }
    },
    "RNT_YN": {
        "label": "Did ... own any land, property, rented to others, or
            receive income from royalties, roomers or boarders, or from
            estates or trusts?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "SRVS_VAL": {
        "label": "Total amount of survivor's income received (combined
            amounts in edited sources sur_val1 and sur_val2 plus the
            unedited sources 3 & 4 starting in 1995)",
        "universe": "SUR_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Income amount"
        }
```

```
    },
    "SS_VAL": {
        "label": "How much did ... receive in social security payments
            during 20.. ?",
        "universe": "SS_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-99999": "Social security"
        }
    },
    "SS_YN": {
        "label": "Who received social security payments either for
            themselves or as combined payments with other family members?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "SSI_VAL": {
        "label": "How much did ... receive in supplemental security income
            during 20..?",
        "universe": "SSI_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
```

```
        "values": {
            "0": "None or niu",
            "1-99999": "Supplemental security income"
        }
    },
    "SSI_YN": {
        "label": "Did ... received ssi?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "STRKUC": {
        "label": "At any time during 20.. did ... receive any union
            unemployment or strike benefits?",
        "universe": "UC_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "SUBUC": {
        "label": "At any time during 20.. did ... receive any supplemental
            unemployment benefits?",
        "universe": "UC_YN = 1",
```

```
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "SUR_SC1": {
        "label": "What was the source of this other widow or survivor income?",
        "universe": "SUR_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1": "Company or union survivor pension",
            "2": "Federal government",
            "3": "Us military retirement survivor pension",
            "4": "State or local gov't survivor pension",
            "5": "Us railroad retirement survivor pension",
            "6": "Worker compensation survivor",
            "7": "Black lung",
            "8": "Regular payments from estates or trusts",
            "9": "Regular payments from annuities or paid-up life insurance",
            "10": "Other or don't know"
        }
    },
    "SUR_SC2": {
        "label": "What was the source of this other widow or survivor income?",
```

```
        "universe": "SUR_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1": "Company or union survivor pension",
            "2": "Federal government",
            "3": "Us military retirement survivor pension",
            "4": "State or local gov't survivor pension",
            "5": "Us railroad retirement survivor pension",
            "6": "Worker compensation survivor",
            "7": "Black lung",
            "8": "Regular payments from estates or trusts",
            "9": "Regular payments from annuities or paid-up life insurance",
            "10": "Other or don't know"
        }
    },
    "SUR_VAL1": {
        "label": "How much did ... receive (survivor source type) during 20.. ?",
        "universe": "SUR_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999,999": "Survivor's income"
        }
    },
    "SUR_VAL2": {
        "label": "How much did ... receive (source type) during 20.. ?",
        "universe": "SUR_YN = 1",
```

```
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999,999": "Survivor's income"
        }
    },
    "SUR_YN": {
        "label": "During 20.. did ... receive any survivor benefits such as widow's pensions, estates, trusts, insurance annuities, or other survivor's income?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "TRDINT_VAL": {
        "label": "Interest amount, exlcuding retirment account interest",
        "universe": "INT_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "all": "Dollar value"
        }
    },
    "UC_VAL": {
```

```
        "label": "How much did ... receive in unemployment benefits during 20..?",
        "universe": "UC_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-99999": "Unemployment compensation"
        }
    },
    "UC_YN": {
        "label": "Any type of unemployment compensation? (Combination of subuc, strkuc, and uctot_yn)",
        "universe": "UC_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_TYP1": {
        "label": "What type of veterans payments did .... receive? (VET_TYP1- disability compensation?)",
        "universe": "VET_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
```

```
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_TYP2": {
        "label": "What type of veterans payments did .... receive? (VET_TYP2- survivor benefits?)",
        "universe": "VET_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_TYP3": {
        "label": "What type of veterans payments did .... receive? (VET_TYP3- veteran's pension?)",
        "universe": "VET_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_TYP4": {
        "label": "What type of veterans payments did .... receive? (VET_TYP4- education assistance?)",
        "universe": "VET_YN = 1",
```

```
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_TYP5": {
        "label": "What type of veterans payments did .... receive? (VET_TYP5- other veteran's payments?)",
        "universe": "VET_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "VET_VAL": {
        "label": "How much did ... receive from veterans' administration during 20..?",
        "universe": "VET_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "None or niu",
            "1-999999": "Veterans' payments"
        }
```

```
},
"VET_YN": {
    "label": "Did ... receive veterans' payments?",
    "universe": "All Persons aged 15+",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Other income",
    "values": {
        "0": "Niu",
        "1": "Yes",
        "2": "No"
    }
},
"WC_TYPE": {
    "label": "What was source of these payments?",
    "universe": "WC_YN = 1",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Other income",
    "values": {
        "0": "Not in universe",
        "1": "State worker's compensation",
        "2": "Employer or employers insurance",
        "3": "Own insurance",
        "4": "Other"
    }
},
"WC_VAL": {
    "label": "How much compensation did ... receive during 20..?",
    "universe": "WC_YN = 1",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Other income",
```

```
        "values": {
            "0": "None or niu",
            "1-99999": "Worker's compensation"
        }
    },
    "WC_YN": {
        "label": "During 20.. did ... receive any worker's compensation
            payments or other payments as a result of a job related injury
            or illness?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Other income",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PAW_TYP": {
        "label": "What type of program did... receive CASH assistance?",
        "universe": "PAW_YN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "Niu",
            "1": "TANF/AFDC",
            "2": "Other",
            "3": "Both"
        }
    },
    "PAW_VAL": {
```

```
        "label": "How much did ... receive in public assistance or welfare during 20..?",
        "universe": "PAW_YN = 1",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "None or niu",
            "1-99999": "Public assistance"
        }
    },
    "PAW_YN": {
        "label": "At any time during 20.., even for one month, did... receive an CASH assistance from a state or county welfare program such as (State program name fill)?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "PENINCL": {
        "label": "Was ... included in that plan?",
        "universe": "PENPLAN = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "Niu",
```

```
            "1": "Yes",
            "2": "No"
        }
    },
    "PENPLAN": {
        "label": "Other than social security did the employer or union that ... worked for in 20.. have a pension or other type of retirement plan?",
        "universe": "WRK_CK = 1",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "WICYN": {
        "label": "Who received WIC?",
        "universe": "Adult female",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Non-cash benefits",
        "values": {
            "0": "Niu",
            "1": "Received WIC",
            "2": "Did not receive WIC"
        }
    },
    "CHCARE_YN": {
        "label": "Paid child care was needed for this child?",
        "universe": "Persons age 15+ with children",
        "type": "Categorical",
```

```
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Supplemental poverty measure",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "CHELSEW_YN": {
        "label": "Does this person have a child living outside the household?",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Supplemental poverty measure",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "CHELSEW_YN": {
        "label": "Does this person have a child living outside the household?",
        "universe": "All persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Supplemental poverty measure",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
```

```
},
"CHSP_VAL": {
    "label": "What is the annual amount of child support paid?",
    "universe": "CHSP_YN = 1",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Supplemental poverty measure",
    "values": {
        "0": "Niu",
        "1-99999": "Amount paid in child support"
    }
},
"CHSP_YN": {
    "label": "Is this person required to pay child support?",
    "universe": "CHELSEW_YN",
    "type": "Categorical",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Supplemental poverty measure",
    "values": {
        "0": "Niu",
        "1": "Yes",
        "2": "No"
    }
},
"CSP_VAL": {
    "label": "How much did ... receive in child support payments?",
    "universe": "CHSP_YN = 1",
    "type": "Continuous",
    "role": "Independent",
    "topic": "Income",
    "subtopic": "Supplemental poverty measure",
    "values": {
        "0": "None or niu",
        "1-99999": "Child support"
```

```
        }
    },
    "CSP_YN": {
        "label": "Did ... receive child support payments?",
        "universe": "All Persons aged 15+",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Supplemental poverty measure",
        "values": {
            "0": "Niu",
            "1": "Yes",
            "2": "No"
        }
    },
    "ACTC_CRD": {
        "label": "Additional child tax credit",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "1-99999": "Dollar amount"
        }
    },
    "AGI": {
        "label": "Adjusted gross income",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
```

```
            "-9999-9999999": "Dollar amount"
        }
    },
    "CTC_CRD": {
        "label": "Child tax credit",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "1-99999": "Dollar amount"
        }
    },
    "EIT_CRED": {
        "label": "Earn income tax credit",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "1-9999": "Dollar amount"
        }
    },
    "FED_RET": {
        "label": "Federal retirement payroll deduction",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
```

```
            "1-999999": "Dollar amount"
        }
    },
    "FEDTAX_AC": {
        "label": "Federal income tax liability, after all credits",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "-9999-9999999": "Dollar amount"
        }
    },
    "FEDTAX_BC": {
        "label": "Federal income tax liability, before credits",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "-9999-9999999": "Dollar amount"
        }
    },
    "FICA": {
        "label": "Social security retirement payroll deduction",
        "universe": "All persons",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
```

```
            "1-99999": "Dollar amount"
        }
    },
    "FILESTAT": {
        "label": "Tax filer status",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "1": "Joint, both<65",
            "2": "Joint, one ><65 & one 65+",
            "3": "Joint, both 65+",
            "4": "Head of household",
            "5": "Single",
            "6": "Non-filer"
        }
    },
    "MARG_TAX": {
        "label": "Marginal tax rate",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "1-99": "Marginal rate"
        }
    },
    "PRSWKXPNS": {
        "label": "Work expenses",
        "universe": "A_AGE > 17 or HHDFMX = 1,2,46, or 47",
        "type": "Continuous",
        "role": "Independent",
```

```
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "1-1999": "Dollar amount"
        }
    },
    "STATETAX_A": {
        "label": "State income tax liability, after all credits",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "-9999-9999999": "Dollar amount"
        }
    },
    "STATETAX_B": {
        "label": "State income tax liability, before credits",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "-9999-9999999": "Dollar amount"
        }
    },
    "TAX_INC": {
        "label": "Taxable income amount",
        "universe": "Tax unit head or dependent filer",
        "type": "Continuous",
        "role": "Independent",
```

```
        "topic": "Income",
        "subtopic": "Tax model items",
        "values": {
            "0": "None",
            "-9999-9999999": "Dollar amount"
        }
    },
    "PERLIS": {
        "label": "Poverty level of persons (Subfamily members have primary family recode)",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Poverty",
        "subtopic": "Poverty",
        "values": {
            "-1": "Not in poverty universe",
            "1": "Below poverty level",
            "2": "100 - 124 percent of the poverty level",
            "3": "125 - 149 percent of the poverty level",
            "4": "150 and above the poverty level"
        }
    },
    "POV_UNIV": {
        "label": "Poverty universe flag",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Poverty",
        "subtopic": "Poverty",
        "values": {
            "0": "Not in poverty universe",
            "1": "In poverty universe"
        }
    },
    "HEA": {
```

```
        "label": "Health status",
        "universe": "All persons",
        "type": "Categorical",
        "role": "Independent",
        "topic": "Health insurance",
        "subtopic": "Health status",
        "values": {
            "1": "Excellent",
            "2": "Very good",
            "3": "Good",
            "4": "Fair",
            "5": "Poor"
        }
    },
    "SPM_ACTC": {
        "label": "SPM units Additional Child Tax Credit",
        "universe": "All persons",
        "type": "Continuous",
        "role": "Independent",
        "topic": "Supplemental poverty measure",
        "subtopic": "SPM unit characteristics",
        "values": {
            "0-99999": "Dollar amount"
        }
    }
}
```

3.5.4 Python Modules

The utility module in Code 3.1 is for basic tasks such as creating a directory, backing up existing files before being overwritten, and importing and exporting a dictionary in JSON format. The encoding module in Code 3.2 is used solely during data encoding as its helper, not its main role. The dataset module in Code 3.3 helps importing and exporting dataset in both feather and CSV formats. The first employs LZ4 compression by default to bring a smaller file than the latter. The EDA module in Code 3.4 is primary for cross tabulation analysis. Its result is exported in CSV format, and its chart is saved in SVG, PGF and PDF formats.

Code 3.1: Utility module (module/utility.py)

```python
import os
import time
import json

# Directory
def create_dir(dir):
    try:
        os.makedirs(dir)
    except FileExistsError:
        pass

# Backup
def backup_duplicate(file_dir, filename, format, backup_dir, info):
    filepath = f"{file_dir}/{filename}.{format}"
    date = time.strftime("%Y%m%d", time.localtime(time.time()))
    if os.path.isfile(filepath):
        backup_subdir = f"{backup_dir}/{date}/{file_dir.replace('../', '')}"
        create_dir(backup_subdir)
        filepath_backup = f"{backup_subdir}/{filename}-backup.{format}"
        os.replace(filepath, filepath_backup)
        if info:
            print(f"{filepath} previously exists")
```

```
            print(f"Back up to {filepath_backup}")
    elif info:
        print(f"{filepath} does not previously exists")

# Import/export dict/JSON
def import_dict(metadatapath):
    with open(metadatapath) as myfile:
        indep_contents = myfile.read()
    return json.loads(indep_contents)

def export_json(dictfile, jsonfile):
    with open(jsonfile, 'w', encoding='utf-8') as f:
        json.dump(dictfile, f, ensure_ascii=False, indent=4)

def export_txt(string, txtfile):
    f = open(txtfile, 'w')
    f.write(string)
    f.close()
```

Code 3.2: Encoding module (module/metaencode.py)

```
import pandas as pd

def extract_dict_cat(indep_dict):
    return {attr: info for (attr, info) in indep_dict.items() if indep_dict[attr]['type'] == 'Categorical'}

def extract_dict_cont(indep_dict):
    return {attr: info for (attr, info) in indep_dict.items() if indep_dict[attr]['type'] == 'Continuous'}

def sort_cols(df_indep, indep_dict):
    sorted_cols = sorted(
        df_indep.head(),
        key=lambda attr: indep_dict[attr]['type'],
```

```
        reverse=True
    )
    return df_indep[sorted_cols]

def indep_info(df_indep, indep_dict):
    df_info = pd.DataFrame({'variable': df_indep.head().columns})
    df_info['type'] = df_info['variable'].apply(lambda attr: indep_dict[
        attr]['type'])
    minmax = df_indep.agg(['min','max']).values.tolist()
    df_info['min'] = minmax[0]
    df_info['max'] = minmax[1]
    del minmax
    return df_info

def count_info(df_info):
    df_count = df_info.groupby('type').count().reset_index()[['type','
        variable']]
    df_count.rename(columns = {'variable': 'count'}, inplace=True)
    df_count.sort_values('type', ascending=False, inplace=True,
        ignore_index=True)
    return df_count
```

Code 3.3: Dataset module (module/dataset.py)

```
import os
import urllib.request
import pandas as pd
import pyarrow

from module.utility import create_dir, backup_duplicate

# Import
def import_dataset(dataset_name, feather_dir, sas_dir='', sas_url=''):
    filepath_feather = f"{feather_dir}/{dataset_name}.feather"

```

```
    if os.path.isfile(filepath_feather):
        print(f"{filepath_feather} is found")
        print(f"{filepath_feather} was previously preprocessed")
        df0 = pd.read_feather(filepath_feather)
    else:
        print(f"{filepath_feather} is not found")
        if sas_dir == '':
            raise Exception("SAS data directory is empty")
        filepath_sas = f"sas_dir/{dataset_name}.sas7bdat"
        if os.path.isfile(filepath_sas):
            print(f"{filepath_sas} is found")
        else:
            print(f"{filepath_sas} is not found")
            create_dir('original/data-orig')
            print(f"{filepath_sas} will be downloaded")
            print("Download starts")
            try:
                urllib.request.urlretrieve(sas_url, filepath_sas)
                print("Download finishes")
            except:
                raise Exception("Download fails")
            print(f"{filepath_sas} is successfully downloaded")
        df0 = pd.read_sas(filepath_sas)

    print(f"\nNumber of original data: {len(df0)}")
    df0 = df0[df0['COV']!=0]
    print(f"An infant born after calendar year (COV = 0) is excluded")
    print(f"Number of training data: {len(df0)}")
    return df0

# Export
def export_dataset(df, file_dir, dataset_name, format, info=True,
    backup_dir=''):
    create_dir(file_dir)
    if format == 'feather' or format == 'csv':
        filepath = f"{file_dir}/{dataset_name}.{format}"
```

```
        if backup_dir != '':
            backup_duplicate(
                file_dir=file_dir, filename=dataset_name,
                format=format,
                backup_dir=backup_dir, info=info
            )
        if format == 'feather':
            df.to_feather(filepath)
        else:
            df.to_csv(filepath, index=False)
        if info:
            print(f"The dataframe is successfully exported to {filepath}")
    else:
        print(f"Input format {format} is unrecognized")
```

Code 3.4: EDA module (module/eda.py)

```
import sys
import time
import pandas as pd
import matplotlib.pyplot as plt

from module.utility import create_dir, backup_duplicate
from module.dataset import export_dataset

# Variables
def describe_var(var_dict, role='independent'):
    num_cat = 0
    num_cont = 0
    for key in var_dict:
        if var_dict[key]['type'] == 'Categorical':
            num_cat += 1
        else:
            num_cont += 1
```

```python
    print(f"There are {num_cat + num_cont} {role} variables of interest: {num_cat} categorical and {num_cont} continuous")

# Cross Tabulation Analysis
def crosstab(df, indep_dict, cont_bins, plot, output_dir, log_filepath, backup_dir=''):
    dir_main = f"{output_dir}/tab-cbins-{cont_bins}"

    for key, val in indep_dict.items():
        fname_main = f"{key}-cbins-{cont_bins}"

        if val['type'] == "Categorical":
            crosstb = pd.crosstab(index=df[key].map(lambda x: val['values'][str(x)]), columns=df['code'])
        else:
            dat = df[[key, 'code']].copy()
            dat['bins'] = pd.cut(dat[key], bins=cont_bins)
            crosstb = pd.crosstab(index=dat['bins'],columns=dat['code'])
            del dat

        print(key)
        print(f"Label: {val['label']}")
        print(f"Universe: {val['universe']}")
        print(f"Type: {val['type']}")
        print(f"Topic: {val['topic']}")
        print(f"Subtopic: {val['subtopic']}")
        print("\n")

        print(f"Code: Employment-based plan (GRP) | Direct-purchase plan (DIR) | Public health insurance (PUB)")
        print(crosstb)
        '''
        dir_crosstb = f"{dir_main}/cross-{cont_bins}"
        create_dir(dir_crosstb)
        export_dataset(
            crosstb,
```

```
    file_dir=f"{dir_crosstb}/feather", dataset_name=f"{fname_main}-cross",
    format='feather', info=False,
    backup_dir=backup_dir
)
export_dataset(
    crosstb,
    file_dir=f"{dir_crosstb}/csv", dataset_name=f"{fname_main}-cross",
    format='csv', info=False,
    backup_dir=backup_dir
)
'''
print("\n")

if plot:
    barplot = crosstb.plot.bar()
    barplot.legend(title='(GRP,DIR,PUB)',
                   bbox_to_anchor=(1,1.02),
                   loc='upper left')
    plt.title(val['label'])
    plt.xlabel(key)
    plt.ylabel('Frequency')
    ls_format = ['svg', 'pgf', 'pdf']
    for format in ls_format:
        dir_fig = f"{dir_main}/figures/{format}"
        figname = f"{key}-cbins-{cont_bins}"
        figpath = f"{dir_fig}/{figname}.{format}"
        create_dir(dir_fig)
        backup_duplicate(
            file_dir=dir_fig, filename=figname,
            format=format,
            backup_dir=backup_dir, info=False
        )
        f = open(log_filepath, 'a')
        temp = sys.stdout
```

```
            sys.stdout = f
            count, tries = 0, 4
            success = False
            while count < tries:
                try:
                    plt.savefig(figpath, bbox_inches='tight')
                    success = True
                    break
                except:
                    pass
                count += 1
            if not success:
                curtime = time.strftime("%Y-%m-%d %H:%M:%S", time.
                    localtime(time.time()))
                print(f"{curtime} | {key}: {figpath} cannot be saved")
            sys.stdout = temp
            f.close()
        #plt.show()

    dftb = crosstb.reset_index().rename_axis(None, axis=1)
    dftb[dftb.columns[1:]] = dftb[dftb.columns[1:]].astype('uint32')
    export_dataset(
        dftb,
        file_dir=f"{dir_main}/feather", dataset_name=fname_main,
        format='feather', info=False,
        backup_dir=backup_dir
    )
    export_dataset(
        dftb,
        file_dir=f"{dir_main}/csv", dataset_name=fname_main,
        format='csv', info=False,
        backup_dir=backup_dir
    )
    print("\n----------------------------------------")
```

3.5.5 Python Classes

Pandas DataFrame is a two-dimensional columnwise data structure. Each column must have the same data type. Although it provides by default rich functionality for data manipulation, additional namespaces can be added to pandas objects by registering custom accessors to serve specific purposes. Health insurance dataset in SAS7BDAT file format is imported as a Pandas DataFrame. All columns are numerical, either `int64` or `float64`.

With the `thesis` namespace (Code 3.5), the data type of a column can be of smaller size through the `retype` method, three dependent variables of interest (GRP, DIR and PUB) can be coded to a string of three character literals, either Y (Yes) or N (No), by the `code` method, and these eight different codes are regrouped to five with numerical values assigned by the `recode` method. Since some categorical values do not start from 0 up to a positive integer as required by the box classifier proposed in Chapter 4, they are encoded to be in this format via the `data` namespace (Code 3.6). Any numerical flags representing a continuous NIU (not in universe) value are converted to zero to become more meaningful. A categorical NIU value is already changed by the previous reordering. The `info` namespace (Code 3.7) sets the number of splitting values or cuts as given on a feature appropriately, not exceeding the number of all possible values for a categorical feature.

Code 3.5: ThesisExtension class (cls/ThesisExtension.py)

```
import re
import pandas as pd

@pd.api.extensions.register_dataframe_accessor("thesis")
class ThesisExtension:
    def __init__(self, pandas_obj):
        #self._validate(pandas_obj, list(indep_dict.keys()) + ['COV'] +
            dep_attrs)
        self.dataset = pandas_obj

    '''
    @staticmethod
    def _validate(obj, cols):
        if any(x not in obj.columns for x in cols):
            raise AttributeError("Some attributes are missing")
```

```
    '''

    def select(self, cols):
        self.dataset.drop(self.dataset.columns.difference(cols), axis=1, inplace=True)

    def show_type(self, option='short'):
        if option.lower() == 'full':
            with pd.option_context('display.max_rows', None, 'display.max_columns', None):
                print(self.dataset.dtypes)
        else:
            print(self.dataset.dtypes)

    @staticmethod
    def retype(ser):
        if all(ser.apply(lambda x: isinstance(x, int))):
            flag_int = True
        elif all(ser.apply(lambda x: x.is_integer())):
            flag_int = True
        else:
            flag_int = False

        if flag_int:
            if all(ser.apply(lambda x: x>=0)):
                if max(ser) <= 255:
                    return ser.astype('uint8')
                elif max(ser) <= 65535:
                    return ser.astype('uint16')
                else:
                    return ser.astype('uint32')
            else:
                if min(ser) >= -128 and max(ser) <= 127:
                    return ser.astype('int8')
                elif min(ser) >= -32768 and max(ser) <= 32767:
                    return ser.astype('int16')
```

```
            else:
                return ser.astype('int32')
        else:
            return ser.astype('float32')

    def code(self, indep_dict, dep_attrs):
        self.select(list(indep_dict.keys()) + ['COV'] + dep_attrs)
        for v in indep_dict.keys():
            if indep_dict[v]['type'] == 'Categorical':
                self.dataset[v] = self.dataset[v].astype('int8').astype('category')
            else:
                self.dataset[v] = self.retype(self.dataset[v])
        self.dataset['COV'] = self.dataset['COV'].astype('int8').astype('category')
        self.dataset[dep_attrs] = self.dataset[dep_attrs].astype('int8')
        self.dataset['class_orig'] = 0
        self.dataset['code_orig'] = ""
        for v in dep_attrs:
            self.dataset[v] = self.dataset[v].replace([2.0, 1.0], [False, True])
            self.dataset['class_orig'] = 2*self.dataset['class_orig'] + self.dataset[v]
            self.dataset['code_orig'] = self.dataset['code_orig'] + self.dataset[v].replace([True, False], ['Y', 'N'])
        self.dataset[dep_attrs] = self.dataset[dep_attrs].astype('category')
        self.dataset['class_orig'] = self.dataset['class_orig'].astype('int8').astype('category')
        self.dataset['code_orig'] = self.dataset['code_orig'].astype('category')

    def recode(self):
        self.dataset['code'] = self.dataset['code_orig'].apply(
            lambda v: 'NY_' if re.match('(NY)', v)
```

```
            else 'Y1Y' if re.match(r'^Y(?:\w*Y)', v) # Raw string to prevent invalid escape sequence '\w'
            else v
        ).astype('category')
        self.dataset['class'] = self.dataset[['class_orig', 'code']].apply(
            lambda v: 2 if v['code'] == 'NY_'
            else 3 if v['code'] == 'YNN'
            else 4 if v['code'] == 'Y1Y'
            else v['class_orig'],
            axis=1
        ).astype('int8').astype('category')
```

Code 3.6: Data class (cls/Data.py)

```
import re
import pandas as pd
from sklearn.preprocessing import LabelEncoder

@pd.api.extensions.register_dataframe_accessor("data")
class Data:
    def __init__(self, pandas_obj, indep_dict):
        self.dataset = pandas_obj
        self.metadata = indep_dict

    def encodecat(self):
        cat_change = ""
        for attr in self.metadata.keys():
            if self.metadata[attr]['type'] == 'Categorical':
                le = LabelEncoder()
                le.fit(self.dataset[attr])
                self.dataset[attr] = list(le.transform(self.dataset[attr]).astype('int8'))
                newkeys = list()
                unseen = 0
                for strval in self.metadata[attr]['values'].keys():
```

```
                    try:
                        newkeys.append(int(le.transform([int(strval)])))
                    except ValueError: # for previously unseen labels
                        unseen -= 1
                        newkeys.append(unseen)
                if list(self.metadata[attr]['values'].keys()) != newkeys:
                    cat_change += attr+"\n"
                newdict = {key: val for key, val in zip(newkeys, self.metadata[attr]['values'].values())}
                self.metadata[attr]['values'] = newdict
        return cat_change[0:-1]

    def encodecont(self):
        pattern = r'(^|[^\w])(niu|universe)([^\w]|$)' # Raw string to prevent invalid escape sequence '\w'
        pattern = re.compile(pattern, re.IGNORECASE)
        cont_nonpos = ""
        for attr in self.metadata.keys():
            if self.metadata[attr]['type'] == 'Continuous':
                flag = False
                for strval in self.metadata[attr]['values'].keys():
                    if not flag:
                        try:
                            if int(strval) <= 0:
                                text = self.metadata[attr]['values'][strval]
                                matches = re.search(pattern, text.replace(',', ' ').lower())
                                if bool(matches):
                                    flag = True
                                    cont_nonpos += attr+"\n"
                                    self.dataset[attr] = self.dataset[attr].apply(lambda v: 0 if v < 0 else v)
                                    break
                        except:
                            pass
                    if flag:
```

```
                try:
                    if int(strval) <= 0:
                        self.metadata[attr]['values'].pop(strval, None)
                except:
                    pass
            if flag:
                self.metadata[attr]['values']['0'] = 'NIU'
        return cont_nonpos[0:-1]
```

Code 3.7: Info class (cls/Info.py)

```
import pandas as pd

# Delete the accessor to avoid warning
try:
    del pd.DataFrame.info
except AttributeError:
    pass

@pd.api.extensions.register_dataframe_accessor("info")
class Info:
    def __init__(self, pandas_obj):
        self._validate(pandas_obj, ['id', 'variable', 'type', 'min', 'max'])
        self.dataset = pandas_obj

    @staticmethod
    def _validate(obj, cols):
        if any(x not in obj.columns for x in cols):
            raise AttributeError("Some attributes are missing")

    def setcut(self, pcont, pcatmax):
        self.dataset['cut'] = 0
```

```
        self.dataset.loc[self.dataset['type'] == 'Continuous', 'cut'] =
            pcont
        self.dataset.loc[self.dataset['type'] == 'Categorical', 'cut'] =
            self.dataset['max'].map(lambda v: min(v, pcatmax))
```

3.5.6 Exploratory Data Analysis (EDA)

This dissertation considers health insurance factors from a range of topics and subtopics as shown in Table 3.5. All infants born after calendar year are excluded in this study because they are not in the scope of health insurance coverage. This results in 157,681 relevant survey participants. Code 3.8 performs exploratory data analysis by using the pandas accessor `thesis` in Code 3.5 to compute the cross tabulation between a health factor (independent variable) and a combination of categorical insurance coverage types (dependent variable) as illustrated in Table 3.6. All continuous values of an independent variables are segmented into 10 bins. In addition, it can significantly compress the original dataset of size 237.4 MB in SAS7BDAT format into the feather and CSV formats of size 14.2 MB and 68.1 MB respectively.

Table 3.5: Categories of health insurance factors

Topic	Subtopic	List of Variables
Demographics	Individual characteristics	A_AGE, A_EXPRRP, A_FAMTYP, A_HGA, A_MARITL, A_PFREL, A_SEX, P_STAT, PEAFEVER, PEDISDRS, PEDISEAR, PEDISEYE, PEDISOUT, PEDISPHY, PEDISREM, PRDISFLG, PRCITSHP, PRDTRACE
Basic CPS items	Edited labor force items	A_MJIND, A_MJOCC, PEIO1COW, PRDISC, PRUNTYPE
	Edited earnings items	A_GRSWK, A_HRLYWK, A_HRSPAY, PRERELG
	Labor force person recodes	A_CIVLF, A_CLSWKR, A_EXPLF, A_LFSR, A_UNCOV, A_UNMEM, A_UNTYPE, A_USLHRS, A_WKSCH, A_WKSLK, A_WKSTAT, PEHRUSLT, PEMLR, PRCOW1, PRPTREA, PRWKSTAT
Work experience	General	CLWK, EARNER, HRSWK, LJCW, NWLKWK, NWLOOK, PHMEMPRS, RSNNOTW, WECLW, WEWKRS, WKSWORK, WORKYN, WRK_CK, WTEMP

Table 3.5: Categories of health insurance factors (continued)

Topic	Subtopic	List of Variables
Income	Earnings	ERN_OTR, ERN_SRCE, ERN_VAL, ERN_YN, FRM_VAL, FRMOTR, FRSE_VAL, FRSE_YN, PEARNVAL, SE_VAL, SEMP_VAL, SEMP_YN, SEOTR, WAGEOTR, WS_VAL, WSAL_VAL, WSAL_YN

Table 3.5: Categories of health insurance factors (continued)

Topic	Subtopic	List of Variables
	Other income	ANN_VAL, ANN_YN, CAP_VAL, CAP_YN, DBTN_VAL, DIS_SC1, DIS_SC2, DIS_VAL1, DIS_VAL2, DIS_YN, DIV_VAL, DIV_YN, DSAB_VAL, DST_SC1, DST_SC1_YNG, DST_SC2, DST_SC2_YNG, DST_VAL1, DST_VAL1_YNG, DST_VAL2, DST_VAL2_YNG, DST_YN, DST_YN_YNG, ED_VAL, ED_YN, FIN_VAL, FIN_YN, INT_VAL, INT_YN, OED_TYP1, OED_TYP2, OED_TYP3, OI_OFF, OI_VAL, OI_YN, PEN_SC1, PEN_SC2, PEN_VAL1, PEN_VAL2, PEN_YN, PNSN_VAL, PTOTVAL, RESNSS1, RESNSS2, RESNSSI1, RESNSSI2, RETCB_VAL, RETCB_YN, RINT_SC1, RINT_SC2, RINT_VAL1, RINT_VAL2, RINT_YN, RNT_VAL, RNT_YN, SRVS_VAL, SS_VAL, SS_YN, SSI_VAL, SSI_YN, STRKUC, SUBUC, SUR_SC1, SUR_SC2, SUR_VAL1, SUR_VAL2, SUR_YN, TRDINT_VAL, UC_VAL, UC_YN, VET_TYP1, VET_TYP2, VET_TYP3, VET_TYP4, VET_TYP5, VET_VAL, VET_YN, WC_TYPE, WC_VAL, WC_YN

Table 3.5: Categories of health insurance factors (continued)

Topic	Subtopic	List of Variables
	Non-cash benefits	PAW_TYP, PAW_VAL, PAW_YN, PENINCL, PENPLAN, WICYN
	Supplemental poverty measure	CHCARE_YN, CHELSEW_YN, CHSP_VAL, CHSP_YN, CSP_VAL, CSP_YN
	Tax model items	ACTC_CRD, AGI, CTC_CRD, EIT_CRED, FED_RET, FEDTAX_AC, FEDTAX_BC, FICA, FILESTAT, MARG_TAX, PRSWKXPNS, STATETAX_A, STATETAX_B, TAX_INC
Poverty	Poverty	PERLIS, POV_UNIV
Health insurance	Health status	HEA
Supplemental poverty measure	SPM unit characteristics	SPM_ACTC

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
A_AGE: Age					
Universe: All Persons					
(-0.085, 8.5]	1,407	5,834	789	628	9,795
(8.5, 17.0]	1,557	6,237	1,079	770	11,822
(17.0, 25.5]	2,238	2,475	1,043	414	8,017
(25.5, 34.0]	2,635	2,749	1,082	594	10,611
(34.0, 42.5]	2,271	2,146	976	613	11,509
(42.5, 51.0]	2,109	2,171	1,157	518	12,081
(51.0, 59.5]	1,606	2,403	1,223	471	9,864
(59.5, 68.0]	1,028	4,854	2,313	2,090	6,097
(68.0, 76.5]	105	5,404	2,602	2,044	254
(76.5, 85.0]	79	4,472	1,977	1,353	115
A_EXPRRP: Expanded relationship code					
Universe: All Persons					
Reference person with relatives	3,693	8,822	4,254	3,365	21,403

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Reference person without relatives	1,603	6,102	2,739	1,413	7,066
Husband	1,049	2,196	1,325	1,016	7,069
Wife	1,482	2,898	1,984	1,426	10,471
Own child	4,337	12,355	2,540	1,553	27,291
Grandchild	377	1,621	137	106	940
Parent	335	1,183	305	174	780
Brother/sister	352	636	127	50	680
Other relative	464	1,219	215	106	908
Foster child	2	107	2	44	2
Nonrelative with relatives	305	514	101	73	816
Partner/roommate	803	780	421	149	2,381
Nonrelative without relatives	233	312	91	20	358
A_FAMTYP: Family type					
Universe: All Persons					
Primary family	11,310	28,667	10,560	7,564	67,373

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Nonfamily householder	1,603	6,102	2,739	1,413	7,066
Related subfamily	779	2,263	327	232	2,169
Unrelated subfamily	59	175	32	29	223
Secondary individual	1,284	1,538	583	257	3,334
A_HGA: Educational attainment					
Universe: All Persons					
Children	2,431	10,167	1,488	1,160	17,629
Less than 1st grade	76	177	31	19	64
1st,2nd,3rd,or 4th grade	170	390	61	21	115
5th or 6th grade	412	666	105	52	283
7th and 8th grade	418	1,035	222	116	794
9th grade	480	1,208	231	126	1,381
10th grade	459	1,363	252	169	1,694
11th grade	495	1,443	307	172	1,814
12th grade no diploma	339	716	159	94	794

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
High school graduate - high school diploma or equivalent	4,267	9,614	3,563	2,174	13,304
Some college but no degree	2,177	4,642	2,282	1,357	10,203
Associate degree in college - occupation/vocation program	465	1,044	589	370	2,681
Associate degree in college - academic program	610	1,260	719	513	3,919
Bachelor's degree (for example: BA,AB,BS)	1,580	3,364	2,738	1,731	15,745
Master's degree (for example: MA,MS,MENG,MED,MSW, MBA)	530	1,221	1,041	1,017	7,264
Professional school degree (for example: MD,DDS,DVM,LLB,JD)	52	189	202	162	1,026
Doctorate degree (for example: PHD,EDD)	74	246	251	242	1,455
A_MARITL: Marital status					
Universe: All Persons					
Married - civilian spouse present	4,911	11,026	6,899	5,333	35,669
Married - AF spouse present	346	11	9	0	86
Married - spouse absent (exc.separated)	261	418	175	97	721
Widowed	282	3,671	1,344	784	741
Divorced	1,186	3,834	1,402	754	4,817

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Separated	356	723	144	101	758
Never married	7,693	19,062	4,268	2,426	37,373
A_PFREL: Primary family relationship					
Universe: All Persons					
Not in primary family	2,946	7,815	3,354	1,699	10,623
Husband	2,408	5,385	3,324	2,794	16,972
Wife	2,501	4,998	3,382	2,404	17,664
Own child	4,337	12,355	2,540	1,553	27,291
Other relative	1,528	4,659	784	436	3,308
Unmarried reference person	1,315	3,533	857	609	4,307
A_SEX: Sex					
Universe: All Persons					
Male	7,804	17,947	6,658	4,710	39,664
Female	7,231	20,798	7,583	4,785	40,501
P_STAT: Status of person identifier					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: All Persons					
Civilian 15+	12,186	28,562	12,747	8,334	62,431
Armed forces	418	16	6	1	105
Children 0-14	2,431	10,167	1,488	1,160	17,629
PEAFEVER: Did you ever serve on active duty in the U.S. Armed Forces?					
Universe: A_AGE greater than or equal to 17					
Not in universe	3,207	11,462	1,745	1,320	20,376
Yes	674	3,025	1,158	1,233	2,498
No	11,154	24,258	11,338	6,942	57,291
PEDISDRS: Does...have difficulty dressing or bathing?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	98	1,545	299	233	224
No	12,088	27,017	12,448	8,101	62,207
PEDISEAR: Is...deaf or does ...have serious difficulty hearing?					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	153	2,024	809	573	683
No	12,033	26,538	11,938	7,761	61,748
PEDISEYE: Is...blind or does...have serious difficulty seeing even when wearing glasses?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	110	1,116	280	202	358
No	12,076	27,446	12,467	8,132	62,073
PEDISOUT: Because of a physical, mental, or emotional condition, does...have difficulty doing errands along such as visiting a doctor's office or shopping?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	223	3,156	638	513	506

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	11,963	25,406	12,109	7,821	61,925
PEDISPHY: Does...have serious difficulty Walking or climbing stairs?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	339	4,767	1,210	900	933
No	11,847	23,795	11,537	7,434	61,498
PEDISREM: Because of a physical, mental, or emotional condition, does...have serious difficulty concentrating, remembering, or making decisions?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	292	2,489	519	367	762
No	11,894	26,073	12,228	7,967	61,669
PRDISFLG: Does this person have any of these disability conditions?					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	732	7,560	2,124	1,569	2,395
No	11,454	21,002	10,623	6,765	60,036
PRCITSHP: Citizenship group					
Universe: All persons					
Native, born in US	11,006	32,887	12,065	8,403	70,326
Native, born in PR or US outlying area	82	345	60	49	326
Native, born abroad of US parent(s)	153	249	92	76	694
Foreign born, US cit by naturalization	1,004	2,975	1,067	650	4,851
Foreign born, not a US citizen	2,790	2,289	957	317	3,968
PRDTRACE: Race					
Universe: All persons					
White only	11,466	27,682	11,885	7,517	63,366
Black only	1,765	6,815	1,011	1,051	7,484
American Indian, Alaskan Native only (AI)	516	902	97	85	837
Asian only	745	2,010	962	561	5,947

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Hawaiian/Pacific Islander only (HP)	89	192	34	41	368
White-Black	150	428	70	58	600
White-AI	131	351	81	96	490
White-Asian	86	111	52	41	613
White-HP	17	50	15	13	112
Black-AI	26	67	5	12	58
Black-Asian	2	8	9	3	45
Black-HP	1	8	1	4	1
AI-Asian	2	6	1	0	6
AI-HP	0	4	0	0	4
Asian-HP	5	17	12	7	72
White-Black-AI	13	44	2	3	32
White-Black-Asian	12	8	0	1	34
White-Black-HP	0	1	0	0	5
White-AI-Asian	2	3	0	0	7
White-AI-HP	0	3	0	0	4

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
White-Asian-HP	4	35	1	2	65
Black-AI-Asian	1	0	0	0	1
White-Black-AI-Asian	0	0	2	0	5
Other 3 race comb.	1	0	0	0	3
Other 4 or 5 race comb.	1	0	1	0	6
A_MJIND: Major industry code					
Universe: A_CLSWKR = 1-7					
Not in universe, or children	6,704	30,326	8,393	5,873	29,260
Agriculture, forestry,fishing, and hunting	268	241	309	79	536
Mining	44	21	24	18	445
Construction	1,114	670	511	214	2,961
Manufacturing	551	501	331	346	5,528
Wholesale and retail trade	1,124	1,336	770	433	5,857
Transportation and utilities	480	474	276	185	2,865
Information	80	117	93	48	978

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Financial activities	310	336	437	233	3,752
Professional and business services	957	926	813	414	6,036
Educational and health services	1,209	1,607	1,088	957	13,296
Leisure and hospitality	1,346	1,367	629	278	3,561
Other services	589	615	457	185	1,854
Public administration	250	208	110	232	3,236
Armed forces	9	0	0	0	0
A_MJOCC: Major occupation recode					
Universe: A_CLSWKR = 1-7					
Not in universe or children	6,704	30,326	8,393	5,873	29,260
Management, business, and financial occupations	866	821	1,144	595	9,953
Professional and related occupations	964	1,023	1,142	951	14,527
Service occupations	2,265	2,597	1,125	547	6,665
Sales and related occupations	791	1,025	687	311	4,343
Office and administrative support occupations	661	797	589	423	5,469

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Farming, fishing, and forestry occupations	177	123	95	31	246
Construction and extraction occupations	948	536	326	160	2,154
Installation, maintenance, and repair occupations	327	215	129	127	1,622
Production occupations	484	417	228	194	2,728
Transportation and material moving occupations	839	865	383	283	3,198
Armed forces	9	0	0	0	0
PEIO1COW: Individual class of worker on first job					
Universe: All persons					
NIU	6,704	30,326	8,393	5,873	29,260
Government-federal	222	120	57	138	1,708
Government-state	189	237	151	213	3,210
Government - local	219	337	196	296	4,045
Private, for profit	6,214	5,951	3,369	2,233	34,815
Private, nonprofit	274	466	323	343	3,933
Self-employed, incorporated	325	323	756	152	1,484

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Self-employed, unincorporated	880	974	986	246	1,703
Without pay	8	11	10	1	7
PRDISC: Discouraged worker recode					
Universe: All persons					
NIU	14,880	38,437	14,165	9,452	79,861
Discouraged worker	40	83	18	4	57
Conditionally interested	73	159	34	28	145
Not available	42	66	24	11	102
PRUNTYPE: Individual class of worker on first job					
Universe: All persons					
NIU	14,304	37,763	13,967	9,302	78,459
Job loser/on layoff	252	341	136	72	797
Other job loser	127	130	38	52	329
Temporary job ended	82	97	17	14	93
Job leaver	69	64	14	11	138

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Re-entrant	162	266	62	38	275
New-entrant	39	84	7	6	74
A_GRSWK: How much does ... usually earn per week at this job before deductions , subject to topcoding, the higher of either the amount of item 25a times Item 25c or the actual item 25d entry will be present					
Universe: PRERELG=1					
(-2.885, 288.5]	14,066	37,929	13,596	9,036	72,547
(288.5, 577.0]	412	407	218	112	1,185
(577.0, 865.5]	285	213	159	122	1,652
(865.5, 1154.0]	111	88	102	92	1,522
(1154.0, 1442.5]	64	47	42	36	979
(1442.5, 1731.0]	34	18	33	27	714
(1731.0, 2019.5]	21	15	20	16	413
(2019.5, 2308.0]	10	9	15	9	314
(2308.0, 2596.5]	13	6	20	9	201

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(2596.5, 2885.0]	19	13	36	36	638
A_HRLYWK: Is ... paid by the hour on this job?					
Universe: PRERELG=1					
Not in universe or children and armed forces	13,245	37,057	13,165	8,715	67,548
Yes	1,320	1,289	662	468	6,463
No	470	399	414	312	6,154
A_HRSPAY: How much does ... earn per hour?					
Universe: A_HRLYWK=1					
(-10.901, 989.1]	14,314	38,046	13,813	9,201	76,286
(989.1, 1979.2]	563	582	312	203	2,116
(1979.2, 2969.3]	112	80	69	58	1,059
(2969.3, 3959.4]	28	24	20	19	391
(3959.4, 4949.5]	10	6	12	5	165
(4949.5, 5939.6]	5	4	10	6	76
(5939.6, 6929.7]	3	1	2	2	40

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(6929.7, 7919.8]	0	1	1	1	21
(7919.8, 8909.9]	0	0	0	0	7
(8909.9, 9900.0]	0	1	2	0	4
PRERELG: Earnings eligibility flag					
Universe: All persons					
Not earnings eligible	13,245	37,057	13,165	8,715	67,548
Earnings eligible	1,790	1,688	1,076	780	12,617
A_CIVLF: Civilian labor force					
Universe: All persons					
Not in universe or children and Armed Forces	6,798	30,466	8,496	5,960	29,588
In universe	8,237	8,279	5,745	3,535	50,577
A_CLSWKR: Class of worker					
Universe: PEMLR=1-3 or (PEMLR=4-7 and person worked in the last 12 months)					
Not in universe or children and armed forces	6,665	30,242	8,386	5,867	29,186

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Private	6,488	6,417	3,692	2,576	38,748
Federal government	222	120	57	138	1,708
State government	189	237	151	213	3,210
Local government	219	337	196	296	4,045
Self-employed-incorporated	325	323	756	152	1,484
Self-employed-not incorporated	880	974	986	246	1,703
Without pay	8	11	10	1	7
Never worked	39	84	7	6	74
A_EXPLF: Experienced labor force employment status					
Universe: PEMLR=1-4					
Not in experienced labor force	6,837	30,550	8,503	5,966	29,662
Employed	7,506	7,297	5,471	3,342	48,871
Unemployed	692	898	267	187	1,632
A_LFSR: Labor force status recode					
Universe: All persons					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Children or Armed Forces	2,849	10,183	1,494	1,161	17,734
Working	7,178	6,826	5,136	3,181	46,957
With job, not at work	328	471	335	161	1,914
Unemployed, looking for work	479	641	138	121	909
Unemployed, on layoff	252	341	136	72	797
Nilf	3,949	20,283	7,002	4,799	11,854
A_UNCOV: On this job, is ... covered by a union or employee association contract?					
Universe: A_UNMEM=2					
Not in universe or children and armed forces	13,962	37,715	13,483	9,016	72,936
Yes	8	11	8	10	108
No	1,065	1,019	750	469	7,121

A_UNMEM: On this job, is ... a member of a labor union or of an employee association similar to a union?

Universe: PRERELG=1

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Not in universe or children and armed forces	13,909	37,669	13,451	8,957	71,925
Yes	53	46	32	59	1,011
No	1,073	1,030	758	479	7,229
A_UNTYPE: Reason for unemployment					
Universe: A_LFSR=3 or 4					
Not in universe or children and Armed Forces	14,304	37,763	13,967	9,302	78,459
Job loser - on layoff	252	341	136	72	797
Other job loser	209	227	55	66	422
Job leaver	69	64	14	11	138
Re-entrant	162	266	62	38	275
New entrant	39	84	7	6	74
A_USLHRS: How many hrs per week does ... usually work at this job?					
Universe: All persons					
(-4.103, 6.3]	8,214	32,313	9,452	6,448	33,848
(6.3, 16.6]	279	647	359	198	1,392

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(16.6, 26.9]	641	1,071	691	288	2,360
(26.9, 37.2]	935	1,099	622	362	3,750
(37.2, 47.5]	4,268	3,105	2,411	1,848	32,501
(47.5, 57.8]	436	291	412	234	4,378
(57.8, 68.1]	186	149	189	74	1,437
(68.1, 78.4]	45	46	57	22	289
(78.4, 88.7]	24	13	28	16	166
(88.7, 99.0]	7	11	20	5	44
A_WKSCH: Labor force by time worked or lost					
Universe: All persons					
Not in universe	6,798	30,466	8,496	5,960	29,588
At work	7,178	6,826	5,136	3,181	46,957
With job, not at work	328	471	335	161	1,914
Unemployed, seeks FT	618	722	197	136	1,316
Unemployed, seeks PT	113	260	77	57	390

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
A_WKSLK: Duration of unemployment					
Universe: PEMLR=3 or 4					
(-0.099, 9.9]	14,748	38,340	14,142	9,435	79,643
(9.9, 19.8]	118	150	44	27	237
(19.8, 29.7]	49	76	17	12	121
(29.7, 39.6]	26	50	9	7	66
(39.6, 49.5]	10	11	4	4	16
(49.5, 59.4]	45	50	11	5	42
(59.4, 69.3]	9	10	3	0	7
(69.3, 79.2]	4	2	0	0	1
(79.2, 89.1]	0	0	0	0	1
(89.1, 99.0]	26	56	11	5	31
A_WKSTAT: Full/part-time status					
Universe: All persons					
Children or Armed Forces	2,849	10,183	1,494	1,161	17,734

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Not in labor force	3,949	20,283	7,002	4,799	11,854
Full-time schedules	5,715	4,390	3,714	2,508	42,413
Part-time for economic reasons, usually FT	267	217	153	48	670
Part-time for non-economic reasons, usually PT	1,200	2,313	1,464	718	5,257
Part-time for economic reasons, usually PT	324	377	140	68	531
Unemployed FT	618	722	197	136	1,316
Unemployed PT	113	260	77	57	390
PEHRUSLT: Hours usually worked last week					
Universe: All persons					
(-4.144, 10.4]	8,336	32,561	9,610	6,541	34,614
(10.4, 24.8]	595	1,159	671	330	2,447
(24.8, 39.2]	1,147	1,420	805	444	4,613
(39.2, 53.6]	4,519	3,253	2,721	1,976	35,068
(53.6, 68.0]	333	257	306	147	2,691
(68.0, 82.4]	87	76	102	42	583

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(82.4, 96.8]	14	7	12	8	106
(96.8, 111.2]	4	11	13	7	36
(111.2, 125.6]	0	0	1	0	7
(125.6, 140.0]	0	1	0	0	0
PEMLR: Major labor force recode					
Universe: All persons					
NIU	2,849	10,183	1,494	1,161	17,734
Employed - at work	7,178	6,826	5,136	3,181	46,957
Employed - absent	328	471	335	161	1,914
Unemployed - on layoff	252	341	136	72	797
Unemployed - looking	479	641	138	121	909
Not in labor force - retired	543	11,004	5,087	3,754	1,768
Not in labor force - disabled	437	4,110	405	359	732
Not in labor force - other	2,969	5,169	1,510	686	9,354

PRCOW1: Class of worker recode-job 1

130

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: All persons					
NIU	6,704	30,326	8,393	5,873	29,260
Federal govt	222	120	57	138	1,708
State govt	189	237	151	213	3,210
Local govt	219	337	196	296	4,045
Private (incl. self-employed incorp.)	6,813	6,740	4,448	2,728	40,232
Self-employed, unincorp.	880	974	986	246	1,703
Without pay	8	11	10	1	7
PRPTREA: Detailed reason for part-time					
Universe: Part time workers					
NIU	12,873	35,620	12,343	8,513	71,585
Usually FT - slack work/business conditions	248	202	136	45	634
Usually FT - seasonal work	13	6	14	1	17
Usually FT - job started/ended during week	6	9	3	2	19
Usually FT - vacation/personal day	90	87	60	57	970

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Usually FT - own illness/injury/medical appt	109	124	79	57	669
Usually FT - holiday (religious or legal)	5	7	3	4	40
Usually FT - child care problems	4	5	7	7	52
Usually FT - other fam/pers obligations	32	25	20	17	206
Usually FT - labor dispute	2	1	0	0	4
Usually FT - weather affected job	70	30	10	5	70
Usually FT - school/training	5	5	1	0	18
Usually FT - civic/military duty	0	1	0	0	4
Usually FT - other reason	119	116	74	44	446
Usually PT - slack work/business conditions	206	223	95	40	345
Usually PT - PT could only find PT work	133	177	61	30	233
Usually PT - seasonal work	12	7	5	2	12
Usually PT - child care problems	64	116	40	16	236
Usually PT - other fam/pers obligations	271	343	248	111	1,221
Usually PT - health/medical limitations	51	199	54	44	123
Usually PT - school/training	303	450	245	98	1,713

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Usually PT - retired/social security limit on earnings	52	440	350	238	228
Usually PT - workweek<35 hours	260	407	251	106	952
Usually PT - other	107	145	142	58	368
PRWKSTAT: Full/part-time work status					
Universe: All persons					
NIU	2,849	10,183	1,494	1,161	17,734
Not in labor force	3,949	20,283	7,002	4,799	11,854
FT hours (35+), usually FT	4,995	3,679	3,226	2,189	38,324
PT for economic reasons, usually FT	267	217	153	48	670
PT for non-economic reasons, usually FT	436	401	254	191	2,479
Not at work, usually FT	227	238	179	105	1,389
PT hrs, usually PT for economic reasons	324	377	140	68	531
PT hrs, usually PT for non-economic	1,099	2,080	1,308	662	4,732
FT hours, usually PT for economic reasons	17	16	12	1	29
FT hours, usually PT for non-economic reasons	40	56	43	22	192

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Not at work, usually part-time	101	233	156	56	525
Unemployed FT	618	722	197	136	1,316
Unemployed PT	113	260	77	57	390
CLWK: Longest job class of worker (recode)					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Private	6,959	7,099	4,733	3,023	41,294
Government	1,009	747	446	710	9,436
Self-employed	849	992	1,008	253	1,614
Without pay	17	12	15	1	15
Never worked	3,770	19,728	6,551	4,348	10,177
EARNER: Earner status recode					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Earner	8,821	8,842	6,188	3,986	52,346

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Nonearner	3,783	19,736	6,565	4,349	10,190
HRSWK: In the weeks that ... worked how may hours did ... usually work per week?					
Universe: WKSWORK > 0					
(-0.099, 9.9]	6,347	30,317	8,296	5,648	28,472
(9.9, 19.8]	354	837	443	259	1,576
(19.8, 29.7]	875	1,550	858	390	2,922
(29.7, 39.6]	1,277	1,534	847	486	4,780
(39.6, 49.5]	5,110	3,719	2,826	2,191	34,221
(49.5, 59.4]	673	461	578	336	5,584
(59.4, 69.3]	276	228	263	122	1,929
(69.3, 79.2]	77	48	74	33	383
(79.2, 89.1]	41	33	33	20	222
(89.1, 99.0]	5	18	23	10	76

LJCW: Longest job class of worker

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: WKSWORK > 0					
Niu	6,201	29,895	8,039	5,508	27,806
Private	6,640	6,757	3,950	2,866	40,016
Federal	569	142	63	152	1,842
State	208	249	160	236	3,440
Local	232	356	223	322	4,154
Self employed incorporated, yes	319	342	783	157	1,278
Self employed incorporated, no or farm	849	992	1,008	253	1,614
Without pay	17	12	15	1	15
NWLKWK: How may different weeks was ... looking for work or on layoff?					
Universe: NWLOOK = 1					
(-0.052, 5.2]	14,892	38,462	14,188	9,469	79,995
(5.2, 10.4]	15	32	7	6	38
(10.4, 15.6]	13	29	4	0	17
(15.6, 20.8]	7	17	4	2	9

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(20.8, 26.0]	14	22	5	4	23
(26.0, 31.2]	3	7	1	0	2
(31.2, 36.4]	3	7	0	0	1
(36.4, 41.6]	6	17	1	1	5
(41.6, 46.8]	4	3	1	0	1
(46.8, 52.0]	78	149	30	13	74
NWLOOK: Even though ... did not work in 20.. did spend and time trying to find a job or on layoff? 4					
Universe: WORKYN = 2					
Niu	11,265	19,017	7,690	5,147	69,988
Yes	176	340	70	41	236
No	3,594	19,388	6,481	4,307	9,941
PHMEMPRS: For how many employers did ... work in 20..? if more than one at same time, only count it as one employer 7					
Universe: WKSWORK > 0					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Niu	6,201	29,895	8,039	5,508	27,806
One employer	7,684	7,738	5,537	3,439	47,029
Two employers	857	848	535	439	4,433
3 or more employers	293	264	130	109	897
RSNNOTW: What was the main reason ... did not work in 20..?					
Universe: WORKYN = 2					
Niu	11,265	19,017	7,690	5,147	69,988
Ill or disabled	508	4,721	503	449	681
Retired	477	10,319	4,709	3,378	1,425
Taking care of home	1,331	1,690	562	231	2,816
Going to school	1,043	2,510	658	254	4,901
Could not find work	209	286	39	21	147
Other	202	202	80	15	207
WECLW: Longest job class of worker (persons 15+)					
Universe: All persons aged 15+					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Not in universe	2,431	10,167	1,488	1,160	17,629
Agriculture (Wage and salary)	220	198	181	60	482
Agriculture (Self-employed)	51	58	120	32	106
Agriculture (Unpaid)	7	3	2	0	4
Nonagriculture (Private household	100	138	60	18	133
Nonagriculture (Other private)	6,338	6,452	3,776	2,801	39,483
Nonagriculture (Government)	1,006	742	444	708	9,407
Nonagriculture (Self-employed)	1,102	1,250	1,606	367	2,733
Nonagriculture (Unpaid)	10	9	13	1	11
Nonagriculture (Never worked)	3,770	19,728	6,551	4,348	10,177
WEWKRS: Weeks worked recode					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Full-year worker (Full time)	5,641	3,827	3,519	2,265	41,178
Full-year worker (Part time)	1,027	1,832	1,095	515	3,717

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Part-year worker (Full time)	1,259	1,434	695	716	4,156
Part-year worker (Part time)	907	1,757	893	491	3,308
Part-year worker (Nonworker)	3,770	19,728	6,551	4,348	10,177
WKSWORK: During 20.. in how many weeks did ... work even for a few hours?					
(include paid vacation and sick leave as work)					
Universe: Persons 15+ with WORKYN = 1					
(-0.052, 5.2]	6,329	30,179	8,164	5,588	28,130
(5.2, 10.4]	147	315	110	98	626
(10.4, 15.6]	180	343	147	104	716
(15.6, 20.8]	229	363	147	131	748
(20.8, 26.0]	318	518	218	197	926
(26.0, 31.2]	184	242	117	79	493
(31.2, 36.4]	235	266	155	111	733
(36.4, 41.6]	300	342	242	163	1,138
(41.6, 46.8]	267	292	165	126	986

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(46.8, 52.0]	6,846	5,885	4,776	2,898	45,669
WORKYN: Did ... work at a job or business at any time during 20..?					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	8,727	8,684	6,108	3,938	52,062
No	3,877	19,894	6,645	4,397	10,474
WRK_CK: Worked last year recode, including temporary and part-time					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	8,834	8,850	6,202	3,987	52,359
No	3,770	19,728	6,551	4,348	10,177
WTEMP: Did ... do any temporary, part-time, or seasonal work even for a few days during 20..?					
Universe: WORKYN = 2					
Niu	11,158	18,851	7,596	5,098	69,691

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	107	166	94	49	297
No	3,770	19,728	6,551	4,348	10,177
ERN_OTR: Wage and salary money earned from other work, Y/N					
Universe: All persons aged 15+					
Niu	6,201	29,895	8,039	5,508	27,806
Yes	819	847	635	496	5,174
No	8,015	8,003	5,567	3,491	47,185
ERN_SRCE: Source of earnings from longest job					
Universe: ERN_YN = 1					
Niu	6,201	29,895	8,039	5,508	27,806
Wage and salary	7,968	7,846	5,179	3,733	50,730
Self employment	809	940	904	224	1,529
Farm self employment	40	52	104	29	85
Without pay	17	12	15	1	15

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
ERN_VAL: How much did ... earn from this employer before deductions in 20..? what was ... net earnings from this business/ farm after expenses during 20..?					
Universe: ERN_YN = 1					
(-11108.998, 101000.8]	14,748	38,542	13,748	9,127	72,515
(101000.8, 212000.6]	239	156	378	286	6,274
(212000.6, 323000.4]	22	24	56	54	780
(323000.4, 434000.2]	9	11	18	16	236
(434000.2, 545000.0]	6	6	13	6	114
(545000.0, 655999.8]	3	3	7	0	55
(655999.8, 766999.6]	1	0	4	1	23
(766999.6, 877999.4]	2	0	4	1	28
(877999.4, 988999.2]	1	0	1	1	21
(988999.2, 1099999.0]	4	3	12	3	119

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
ERN_YN: Earnings from employer or net earnings from business/ farm after expenses from longest job during 20.. ?					
Universe: WORKYN=1 or WTEMP=1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	8,817	8,838	6,187	3,986	52,344
No	3,787	19,740	6,566	4,349	10,192
FRM_VAL: Amount of farm self-employment earnings from secondary source					
Universe: FRMOTR = 1					
(-10288.999, 19000.9]	15,028	38,744	14,230	9,484	80,131
(19000.9, 48000.8]	3	1	7	3	25
(48000.8, 77000.7]	3	0	0	5	7
(77000.7, 106000.6]	1	0	4	3	1
(251000.1, 280000.0]	0	0	0	0	1
FRMOTR: Receiving farm self-employment from secondary source					
Universe: ERN_OTR = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Niu	14,212	37,902	13,606	9,002	75,001
Yes	86	56	73	43	478
No	737	787	562	450	4,686
FRSE_VAL: Total amount of farm self-employment earnings					
Universe: ERN_YN=1 or FRMOTR=1					
(-20767.998, 57001.8]	15,029	38,739	14,206	9,483	80,136
(57001.8, 134001.6]	6	5	29	10	25
(134001.6, 211001.4]	0	1	2	0	3
(211001.4, 288001.2]	0	0	3	1	1
(442000.8, 519000.6]	0	0	0	1	0
(673000.2, 750000.0]	0	0	1	0	0
FRSE_YN: Receiving any farm self-employment					
Universe: ERN_YN=1 or FRMOTR=1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	122	105	170	70	560

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	12,482	28,473	12,583	8,265	61,976
PEARNVAL: Total persons earnings					
Universe: All persons aged 15+					
(-12083.998, 198500.8]	14,962	38,669	14,069	9,370	78,229
(198500.8, 407000.6]	53	62	126	111	1,506
(407000.6, 615500.4]	11	11	22	8	220
(615500.4, 824000.2]	3	0	10	2	53
(824000.2, 1032500.0]	3	2	5	3	62
(1032500.0, 1240999.8]	3	1	8	1	93
(1240999.8, 1449499.6]	0	0	1	0	0
(1449499.6, 1657999.4]	0	0	0	0	1
(1866499.2, 2074999.0]	0	0	0	0	1
SE_VAL: Amount of own business self-employment earnings from secondary source					
Universe: SEOTR = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-10558.999, 46000.9]	15,027	38,736	14,220	9,484	80,099
(46000.9, 102000.8]	8	7	14	6	45
(102000.8, 158000.7]	0	2	5	2	6
(158000.7, 214000.6]	0	0	0	2	4
(214000.6, 270000.5]	0	0	0	1	1
(270000.5, 326000.4]	0	0	2	0	5
(326000.4, 382000.3]	0	0	0	0	3
(382000.3, 438000.2]	0	0	0	0	1
(494000.1, 550000.0]	0	0	0	0	1
SEMP_VAL: Total own business self-employment earnings (combined amounts in ern-val, if ern-srce=2, and se-val)					
Universe: ERN_YN=1 or SEOTR=1					
(-21117.997, 92001.7]	14,989	38,698	14,106	9,464	79,943
(92001.7, 204001.4]	39	41	111	24	179
(204001.4, 316001.1]	2	3	15	4	20

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(316001.1, 428000.8]	0	2	2	2	11
(428000.8, 540000.5]	3	1	2	1	4
(540000.5, 652000.2]	0	0	1	0	2
(652000.2, 763999.9]	0	0	1	0	2
(763999.9, 875999.6]	0	0	1	0	1
(987999.3, 1099999.0]	2	0	2	0	3
SEMP_YN: Receiving own business self-employment, y/n					
Universe: ERN_YN=1 or SEOTR=1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	942	1,075	1,061	320	2,577
No	11,662	27,503	11,692	8,015	59,959
SEOTR: Receiving own business self-employment, y/n					
Universe: ERN_YN=1 or SEOTR=1					
Niu	14,214	37,904	13,607	9,000	74,996
Yes	148	149	171	101	1,077

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	673	692	463	394	4,092
WAGEOTR: Receiving wage and salary earnings from other employers, y/n					
Universe: ERN_OTR = 1					
Niu	14,218	37,901	13,607	9,002	74,994
Yes	786	807	590	471	4,927
No	31	37	44	22	244
WS_VAL: Amount of wage and salary earnings from other employers					
Universe: ERN_OTR = 1					
(-1099.999, 109999.9]	15,033	38,738	14,235	9,491	80,092
(109999.9, 219999.8]	1	7	5	3	59
(219999.8, 329999.7]	1	0	1	1	3
(329999.7, 439999.6]	0	0	0	0	5
(439999.6, 549999.5]	0	0	0	0	1
(879999.2, 989999.1]	0	0	0	0	3

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(989999.1, 1099999.0]	0	0	0	0	2
WSAL_VAL: Total wage and salary earnings (combined amounts in ern-val, if ern-srce=1, and ws-val)					
Universe: ERN_YN=1 or WAGEOTR=1					
(-1999.999, 199999.9]	14,976	38,684	14,113	9,393	78,320
(199999.9, 399999.8]	38	44	85	87	1,377
(399999.8, 599999.7]	13	13	25	9	247
(599999.7, 799999.6]	3	1	4	1	56
(799999.6, 999999.5]	3	0	4	2	49
(999999.5, 1199999.4]	2	3	10	3	114
(1199999.4, 1399999.3]	0	0	0	0	1
(1799999.1, 1999999.0]	0	0	0	0	1
WSAL_YN: Receiving wage and salary earnings					
Universe: ERN_YN=1 or WAGEOTR=1					
Niu	2,431	10,167	1,488	1,160	17,629

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	8,025	7,920	5,259	3,764	50,886
No	4,579	20,658	7,494	4,571	11,650
ANN_VAL: Retirement income, annuities amount					
Universe: ANN_YN = 1					
(-396.0, 39600.0]	15,030	38,705	14,208	9,456	80,136
(39600.0, 79200.0]	4	28	23	34	18
(79200.0, 118800.0]	1	7	6	3	8
(118800.0, 158400.0]	0	3	2	0	2
(158400.0, 198000.0]	0	2	0	1	0
(356400.0, 396000.0]	0	0	2	1	1
ANN_YN: Retirement income, annuities, y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	26	634	573	422	219

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	12,578	27,944	12,180	7,913	62,317
CAP_VAL: Capital gains value					
Universe: CAP_YN = 1					
(-999.999, 99999.9]	15,031	38,725	14,211	9,473	80,085
(99999.9, 199999.8]	2	13	16	16	35
(199999.8, 299999.7]	2	6	6	5	24
(299999.7, 399999.6]	0	1	3	0	9
(399999.6, 499999.5]	0	0	1	0	3
(499999.5, 599999.4]	0	0	1	1	0
(699999.3, 799999.2]	0	0	1	0	7
(899999.1, 999999.0]	0	0	2	0	2
CAP_YN: Yes/no answer to âDid you receive capital gain from your shares of stock or mutual fund?’					
Universe: DIV_YN = 1					
Niu	14,044	36,074	11,363	7,534	66,843

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	176	734	958	693	3,176
No	815	1,937	1,920	1,268	10,146
DBTN_VAL: Total amount of retirement distributions received (dst_val1 + dst_val2)					
Universe: DST_VAL1>0 OR DST_VAL2>0					
(-999.999, 99999.9]	15,033	38,711	14,203	9,460	80,139
(99999.9, 199999.8]	2	32	35	32	23
(199999.8, 299999.7]	0	2	2	1	2
(299999.7, 399999.6]	0	0	0	1	0
(399999.6, 499999.5]	0	0	1	0	1
(899999.1, 999999.0]	0	0	0	1	0
DIS_SC1: What was the source of disability income?					
Universe: DIS_YN=1					
Niu	14,947	38,270	14,130	9,359	79,707
Worker's compensation	16	32	11	15	96

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Company or union disability	10	48	19	34	123
Federal government disability	6	58	9	10	15
Us military retirement disability	18	45	10	8	12
State or local gov't employee disability	14	92	21	25	56
Us railroad retirement disability	0	6	2	0	1
Accident or disability insurance	8	32	16	17	60
Blacklung miners disability	0	0	0	1	0
State temporary sickness	3	1	2	1	9
Other or don't know	13	161	21	25	86
DIS_SC2: What was the source of disability income?					
Universe: DIS_YN=1					
Niu	15,035	38,740	14,240	9,493	80,158
Federal government disability	0	0	1	0	0
Us military retirement disability	0	1	0	0	0
State or local gov't employee disability	0	2	0	1	3

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Other or don't know	0	2	0	1	4
DIS_VAL1: How much did ... receive (source type) during 20.. ?					
Universe: DIS_SC1>0					
(-100.0, 10000.0]	14,993	38,533	14,185	9,428	80,005
(10000.0, 20000.0]	26	144	25	31	78
(20000.0, 30000.0]	7	33	16	23	40
(30000.0, 40000.0]	4	13	4	4	15
(40000.0, 50000.0]	3	10	1	2	11
(50000.0, 60000.0]	1	0	0	1	1
(60000.0, 70000.0]	1	1	1	0	1
(70000.0, 80000.0]	0	1	1	1	4
(80000.0, 90000.0]	0	1	0	1	0
(90000.0, 100000.0]	0	9	8	4	10
DIS_VAL2: How much did ... receive (source type) during 20.. ?					
Universe: DIS_SC2>0					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-23.672, 2367.2]	15,035	38,740	14,240	9,493	80,158
(4734.4, 7101.6]	0	1	0	0	4
(7101.6, 9468.8]	0	0	0	0	1
(11836.0, 14203.2]	0	0	0	0	1
(14203.2, 16570.4]	0	3	1	2	0
(21304.8, 23672.0]	0	1	0	0	1
DIS_YN: Other than social security did ... receive any income in 20.. as a result of health problems?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	88	475	111	136	458
No	12,516	28,103	12,642	8,199	62,078
DIV_VAL: How much did ... receive in dividends from stocks or mutual funds during 20.. ?					
Universe: DIV_YN = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-999.999, 99999.9]	15,031	38,730	14,217	9,476	80,108
(99999.9, 199999.8]	4	10	14	14	36
(199999.8, 299999.7]	0	3	6	3	16
(299999.7, 399999.6]	0	2	2	0	2
(699999.3, 799999.2]	0	0	0	2	0
(899999.1, 999999.0]	0	0	2	0	3
DIV_YN: Did ... receive dividends?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	583	1,873	2,246	1,575	8,875
No	12,021	26,705	10,507	6,760	53,661
DSAB_VAL: Total amount of disability income received, combined amounts in edited sources one and two					
Universe: DIS_VAL1>0 OR DIS_VAL2>0					
(-100.0, 10000.0]	14,993	38,529	14,184	9,427	80,002

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(10000.0, 20000.0]	26	147	25	32	77
(20000.0, 30000.0]	7	33	17	23	44
(30000.0, 40000.0]	4	14	4	3	15
(40000.0, 50000.0]	3	10	1	2	11
(50000.0, 60000.0]	1	0	0	2	1
(60000.0, 70000.0]	1	1	1	0	1
(70000.0, 80000.0]	0	1	1	1	4
(80000.0, 90000.0]	0	1	0	1	0
(90000.0, 100000.0]	0	9	8	4	10
DST_SC1: Retirement income, distribution source 1					
Universe: DST_VAL1 > 0 and a_age >= 58					
Niu	14,982	37,052	12,699	8,267	79,685
401k account	28	684	568	499	249
403b account	0	49	39	48	20
Roth ira	2	114	99	60	24

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Regular ira	17	739	715	499	115
Keogh plan	0	1	3	3	1
Sep plan (simplified employee pension)	1	12	27	18	5
Other type of retirement account	5	94	91	101	66
DST_SC1_YNG: Retriement Distribution source 1, person under age 58					
Universe: DST_YN_YNG = 1 and a_age < 58					
Niu	14,950	38,651	14,163	9,424	79,246
401k account	52	60	45	47	653
403b account	4	3	3	4	41
Roth ira	13	11	5	7	66
Regular ira	11	15	20	4	107
Sep plan (simplified employee pension)	0	1	1	0	3
Other type of retirement account	5	4	4	9	49

DST_SC2: Retirement income, distribution source 2

Universe: DST_VAL2 > 0 and a_age >= 58

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Niu	15,034	38,662	14,160	9,433	80,151
403b account	0	4	5	5	1
Roth ira	1	12	12	6	3
Regular ira	0	51	45	38	9
Keogh plan	0	0	1	0	0
Sep plan (simplified employee pension)	0	3	2	3	0
Other type of retirement account	0	13	16	10	1
DST_SC2_YNG: Retriement Distribution source 2, person under age 58					
Universe: DST_VAL_YNG > 0 and a_age < 58					
Niu	15,031	38,739	14,241	9,494	80,146
403b account	0	0	0	0	1
Roth ira	2	2	0	1	9
Regular ira	2	2	0	0	5
Sep plan (simplified employee pension)	0	2	0	0	3
Other type of retirement account	0	0	0	0	1

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
DST_VAL1: Retirement income amount, distribution source 1					
Universe: DST_SC1 = 1					
(-999.999, 99999.9]	15,033	38,711	14,207	9,463	80,139
(99999.9, 199999.8]	2	32	31	29	23
(199999.8, 299999.7]	0	2	2	1	2
(299999.7, 399999.6]	0	0	0	1	0
(399999.6, 499999.5]	0	0	1	0	1
(899999.1, 999999.0]	0	0	0	1	0
DST_VAL1_YNG: Retriement Distribution amount 1, under age 58					
Universe: DST_SC1_YNG = 1					
(-999.999, 99999.9]	15,033	38,743	14,240	9,494	80,137
(99999.9, 199999.8]	1	1	0	1	17
(199999.8, 299999.7]	0	1	1	0	6
(299999.7, 399999.6]	1	0	0	0	1
(399999.6, 499999.5]	0	0	0	0	3

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(899999.1, 999999.0]	0	0	0	0	1
DST_VAL2: Retirement income amount, distribution source 2					
Universe: DST_SC2 = 1					
(-75.0, 7500.0]	15,034	38,719	14,208	9,469	80,158
(7500.0, 15000.0]	1	20	21	15	4
(15000.0, 22500.0]	0	0	3	2	0
(22500.0, 30000.0]	0	0	1	5	3
(30000.0, 37500.0]	0	1	1	0	0
(37500.0, 45000.0]	0	0	1	1	0
(45000.0, 52500.0]	0	1	0	0	0
(52500.0, 60000.0]	0	1	4	1	0
(60000.0, 67500.0]	0	2	0	0	0
(67500.0, 75000.0]	0	1	2	2	0

DST_VAL2_YNG: Retriement Distribution amount 2, under age 58

Universe: DST_SC2_YNG = 1

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-43.0, 4300.0]	15,032	38,742	14,241	9,494	80,157
(4300.0, 8600.0]	2	1	0	1	4
(8600.0, 12900.0]	0	1	0	0	1
(21500.0, 25800.0]	0	0	0	0	1
(30100.0, 34400.0]	0	1	0	0	2
(38700.0, 43000.0]	1	0	0	0	0
DST_YN: Retirement income distribution y/n					
Universe: Persons aged 58 and over (a_age >= 58)					
Niu	13,643	23,641	7,180	3,933	72,508
Yes	53	1,693	1,543	1,228	480
No	1,339	13,411	5,518	4,334	7,177
DST_YN_YNG: Retiement Distribution Recipiency, person under age 58					
Universe: Persons under age 58 (a_age < 58)					
Niu	3,823	25,271	8,549	6,722	25,286
Yes	85	94	78	71	919

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	11,127	13,380	5,614	2,702	53,960
ED_VAL: Total amount of educational assistance received (combined amounts in pell grant and other educational) assistance during 20.. ?					
Universe: ED_YN = 1					
(-99.999, 9999.9]	14,940	38,640	14,141	9,451	79,622
(9999.9, 19999.8]	62	73	50	21	289
(19999.8, 29999.7]	20	17	26	10	141
(29999.7, 39999.6]	7	8	9	9	59
(39999.6, 49999.5]	2	2	2	1	28
(49999.5, 59999.4]	4	2	5	2	16
(59999.4, 69999.3]	0	1	4	0	3
(69999.3, 79999.2]	0	0	0	0	2
(79999.2, 89999.1]	0	2	2	0	3
(89999.1, 99999.0]	0	0	2	1	2

ED_YN: Did ... receive educational assistance?

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	430	611	303	159	1,946
No	12,174	27,967	12,450	8,176	60,590
FIN_VAL: How much did ... receive in financial assistance income during 20.. ?					
Universe: FIN_YN = 1					
(-500.0, 50000.0]	15,033	38,742	14,238	9,491	80,147
(50000.0, 100000.0]	2	3	3	4	15
(100000.0, 150000.0]	0	0	0	0	2
(450000.0, 500000.0]	0	0	0	0	1
FIN_YN: Did ... receive financial assistance?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	166	321	141	75	406

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	12,438	28,257	12,612	8,260	62,130
INT_VAL: Edited total combined interest income					
Universe: INT_YN = 1					
(-280.0, 28000.0]	14,979	38,527	13,944	9,220	78,544
(28000.0, 56000.0]	31	126	164	145	937
(56000.0, 84000.0]	16	41	60	46	281
(84000.0, 112000.0]	7	45	66	73	354
(112000.0, 140000.0]	1	4	7	10	35
(140000.0, 168000.0]	1	1	0	0	11
(168000.0, 196000.0]	0	0	0	1	1
(196000.0, 224000.0]	0	1	0	0	1
(252000.0, 280000.0]	0	0	0	0	1
INT_YN: Edited total combined interest income, y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	3,950	9,847	7,759	5,700	40,283
No	8,654	18,731	4,994	2,635	22,253
OED_TYP1: Source 1 other than gi bill received (OED_TYP1- source of other government assistance)					
Universe: ED_YN = 1					
Niu	14,584	38,089	13,928	9,331	78,173
Yes	102	144	62	44	321
No	349	512	251	120	1,671
OED_TYP2: Source 2 other than gi bill received (OED_TYP2- scholarships, grants etc. from the school)					
Universe: ED_YN = 1					
Niu	14,584	38,089	13,928	9,331	78,173
Yes	146	211	153	61	986
No	305	445	160	103	1,006

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
OED_TYP3: Source other than gi bill received (OED_TYP3- other assistance (employers friends, etc.)					
Universe: ED_YN = 1					
Niu	14,584	38,089	13,928	9,331	78,173
Yes	51	51	41	26	375
No	400	605	272	138	1,617
OI_OFF: Other income sources					
Universe: OI_YN = 1					
Niu	14,824	38,368	14,077	9,332	79,115
Social security	1	2	1	0	3
Private pensions	0	5	3	3	5
Afdc	6	6	3	0	13
Other public assistance	0	2	0	1	5
Dividends	0	1	0	0	0
Rents or royalties	2	1	3	0	7

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
State disability payments (worker's comp)	1	1	0	1	1
Disability payments (own insurance)	0	1	0	0	4
Annuities or paid up insurance policies	1	1	1	0	2
Anything else	192	330	137	150	969
Alimony	8	27	16	8	41
OI_VAL: How much did ... receive in other incomes					
Universe: OI_YN = 1					
(-950.0, 95000.0]	15,033	38,744	14,240	9,488	80,149
(95000.0, 190000.0]	2	0	1	5	12
(190000.0, 285000.0]	0	0	0	1	0
(285000.0, 380000.0]	0	1	0	0	1
(380000.0, 475000.0]	0	0	0	1	1
(475000.0, 570000.0]	0	0	0	0	1
(855000.0, 950000.0]	0	0	0	0	1
OI_YN: Did ... receive cash income not already covered from any other source?					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: All Persons aged 15+					
None or niu	2,431	10,167	1,488	1,160	17,629
Yes	211	377	164	163	1,050
No	12,393	28,201	12,589	8,172	61,486
PEN_SC1: Retirement income, pension source 1					
Universe: PEN_YN = 1					
Niu	14,862	36,035	12,394	7,307	79,002
Company pension	48	1,416	1,039	872	419
Union pension	15	264	176	183	94
Federal government pension	22	173	76	262	130
State government pension	21	524	397	643	336
Local government pension	10	162	84	168	129
Us military pension	56	118	15	15	35
Us railroad retirement	0	10	6	8	2
Other	1	43	54	37	18

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
PEN_SC2: Retirement income, pension source 2					
Universe: PEN_VAL2 $>$ 0					
Niu	15,028	38,634	14,198	9,420	80,137
Union pension	1	21	16	20	4
Federal government pension	0	8	3	6	1
State government pension	1	17	9	29	8
Local government pension	0	9	4	6	6
Us military pension	5	49	5	11	7
Us railroad retirement	0	1	0	0	0
Other	0	6	6	3	2
PEN_VAL1: Retirement income amount, pension source 1					
Universe: PEN_SC1 $>$ 0					
(-999.999, 99999.9]	15,031	38,709	14,220	9,454	80,129
(99999.9, 199999.8]	4	21	16	33	27
(199999.8, 299999.7]	0	3	1	3	3

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(299999.7, 399999.6]	0	3	1	1	1
(399999.6, 499999.5]	0	3	1	0	2
(599999.4, 699999.3]	0	2	0	0	0
(699999.3, 799999.2]	0	1	0	0	0
(899999.1, 999999.0]	0	3	2	4	3
PEN_VAL2: Retirement income amount, pension source 2					
Universe: PEN_SC2 > 0					
(-360.0, 36000.0]	15,033	38,737	14,239	9,485	80,158
(36000.0, 72000.0]	1	6	1	7	6
(72000.0, 108000.0]	1	1	1	2	1
(108000.0, 144000.0]	0	0	0	1	0
(324000.0, 360000.0]	0	1	0	0	0
PEN_YN: Retirement income, pension y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	173	2,710	1,847	2,188	1,163
No	12,431	25,868	10,906	6,147	61,373
PNSN_VAL: Total combined amount of pension income received from all pension sources					
Universe: PEN_YN = 1					
(-999.999, 99999.9]	15,030	38,707	14,219	9,451	80,125
(99999.9, 199999.8]	5	22	17	36	31
(199999.8, 299999.7]	0	3	1	3	3
(299999.7, 399999.6]	0	4	1	1	1
(399999.6, 499999.5]	0	3	1	0	2
(599999.4, 699999.3]	0	2	0	0	0
(699999.3, 799999.2]	0	1	0	0	0
(899999.1, 999999.0]	0	3	2	4	3
PTOTVAL: Total persons income					
Universe: All Persons aged 15+					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-12094.703, 199571.3]	14,933	38,563	13,963	9,239	77,720
(199571.3, 409141.6]	78	150	209	217	1,918
(409141.6, 618711.9]	13	21	35	24	282
(618711.9, 828282.2]	5	5	14	3	74
(828282.2, 1037852.5]	3	4	4	7	60
(1037852.5, 1247422.8]	3	2	13	5	100
(1247422.8, 1456993.1]	0	0	2	0	8
(1456993.1, 1666563.4]	0	0	0	0	1
(1876133.7, 2085704.0]	0	0	1	0	2
RESNSS1: What were the reasons (you/name) (was/were) getting Social Security Income last year?					
Universe: SS_YN = 1					
Niu	14,638	25,268	8,599	5,024	78,937
Retired	195	10,639	5,128	3,924	693
Disabled (adult or child)	138	2,272	280	266	293

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Widowed	25	208	93	57	51
Spouse	4	89	39	45	9
Surviving child	16	54	11	18	77
Dependent child	9	59	12	7	36
On behalf of surviving, dependent, or disabled child(ren)	8	61	6	10	51
Other (adult or child)	2	95	73	144	18
RESNSS2: What were the reasons (you/name) (was/were) getting Social Security Income last year?					
Universe: SS_YN = 1					
Niu	15,018	38,345	14,129	9,409	80,099
Disabled (adult or child)	2	164	28	20	7
Widowed	0	103	50	31	3
Spouse	3	20	4	4	3
Surviving child	0	5	2	0	3
Dependent child	0	4	0	0	2

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
On behalf of surviving, dependent, or disabled child(ren)	11	89	22	21	47
Other (adult or child)	1	15	6	10	1
RESNSSI1: What were the reasons (you/name) (was/were) getting Supplemental Security Income last year?					
Universe: SSI_YN = 1					
Niu	14,976	36,504	14,140	9,303	80,055
Disabled (adult or child)	39	1,992	77	159	66
Blind (adult or child)	0	25	2	1	2
On behalf of a disabled child	16	58	6	10	25
On behalf of a blind child	0	2	0	0	1
Other (adult or child)	4	164	16	22	16
RESNSSI2: What were the reasons (you/name) (was/were) getting Supplemental Security Income last year?					
Universe: SSI_YN = 1					
Niu	15,031	38,715	14,240	9,493	80,162

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Blind (adult or child)	0	5	0	0	0
On behalf of a disabled child	2	14	0	1	1
Other (adult or child)	2	11	1	1	2
RETCB_VAL: Retirement contributiion, amount					
Universe: RETCB_YN = 1					
(-32.0, 3200.0]	14,564	38,456	13,704	8,916	67,888
(3200.0, 6400.0]	256	114	243	252	5,011
(6400.0, 9600.0]	63	60	116	117	2,102
(9600.0, 12800.0]	62	47	52	56	1,625
(12800.0, 16000.0]	31	18	22	30	945
(16000.0, 19200.0]	37	10	50	46	1,617
(19200.0, 22400.0]	10	17	18	23	279
(22400.0, 25600.0]	12	20	32	48	632
(25600.0, 28800.0]	0	0	0	2	22
(28800.0, 32000.0]	0	3	4	5	44

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
RETCB_YN: Retirement contribution, y/n					
Universe: All people 15 years and over					
Niu	13,470	34,901	10,249	6,228	53,437
Yes	1,034	793	1,070	1,247	21,810
No	531	3,051	2,922	2,020	4,918
RINT_SC1: Interest income, retirement source 1					
Universe: RINT_YN = 1					
Niu	13,470	34,901	10,249	6,228	53,437
401k account	973	1,925	1,791	1,791	19,885
403b account	60	121	118	188	2,112
Roth ira	216	421	583	292	1,465
Regular ira	163	1,063	1,207	711	1,239
Keogh plan	0	5	11	4	23
Sep plan (simplified employee pension)	19	49	98	43	305
Other type of retirement account	134	260	184	238	1,699

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
RINT_SC2: Interest income, retirement source 2					
Universe: RINT_YN = 1					
Niu	14,818	38,284	13,614	8,981	75,781
403b account	10	27	23	34	351
Roth ira	92	113	154	163	2,018
Regular ira	65	255	342	228	1,284
Keogh plan	0	1	6	0	10
Sep plan (simplified employee pension)	7	16	48	18	162
Other type of retirement account	43	49	54	71	559
RINT_VAL1: Interest income amt, retirement source 1					
Universe: RINT_SC1 > 0					
(-100.0, 10000.0]	14,936	38,372	13,795	9,102	77,436
(10000.0, 20000.0]	51	173	178	147	1,160
(20000.0, 30000.0]	17	60	86	68	496
(30000.0, 40000.0]	9	45	56	40	274

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(40000.0, 50000.0]	6	28	43	46	287
(50000.0, 60000.0]	3	5	16	7	85
(60000.0, 70000.0]	3	9	12	10	75
(70000.0, 80000.0]	5	13	9	17	71
(80000.0, 90000.0]	0	2	6	4	26
(90000.0, 100000.0]	5	38	40	54	255
RINT_VAL2: Interest income amt, retirement source 2					
Universe: RINT_SC2 > 0					
(-100.0, 10000.0]	15,015	38,701	14,182	9,431	79,816
(10000.0, 20000.0]	9	14	22	25	140
(20000.0, 30000.0]	0	13	14	16	44
(30000.0, 40000.0]	2	2	2	4	39
(40000.0, 50000.0]	3	6	7	3	15
(50000.0, 60000.0]	2	2	1	3	11
(60000.0, 70000.0]	1	0	1	1	14

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(70000.0, 80000.0]	0	2	2	3	12
(80000.0, 90000.0]	0	0	1	0	9
(90000.0, 100000.0]	3	5	9	9	65
RINT_YN: Interest income - retirement, y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	1,565	3,844	3,992	3,267	26,728
No	11,039	24,734	8,761	5,068	35,808
RNT_VAL: How much did ... receive in income from rent after expenses during 20..?					
Universe: RNT_YN = 1					
(-11008.998, 91000.8]	15,031	38,718	14,217	9,473	80,117
(91000.8, 192000.6]	2	25	18	20	26
(192000.6, 293000.4]	0	1	1	0	10
(293000.4, 394000.2]	1	1	1	0	6

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(394000.2, 495000.0]	0	0	1	1	2
(495000.0, 595999.8]	0	0	0	0	1
(595999.8, 696999.6]	1	0	0	0	1
(898999.2, 999999.0]	0	0	3	1	2
RNT_YN: Did ... own any land, property, rented to others, or receive income from royalties, roomers or boarders, or from estates or trusts?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	290	918	1,088	677	2,802
No	12,314	27,660	11,665	7,658	59,734
SRVS_VAL: Total amount of survivor's income received (combined amounts in edited sources sur_val1 and sur_val2 plus the unedited sources 3 & 4 starting in 1995)					
Universe: SUR_YN = 1					
(-200.0, 20000.0]	15,022	38,674	14,181	9,420	80,073

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(20000.0, 40000.0]	7	39	39	48	47
(40000.0, 60000.0]	4	18	8	14	13
(60000.0, 80000.0]	0	1	3	0	8
(80000.0, 100000.0]	2	11	8	13	20
(100000.0, 120000.0]	0	1	1	0	1
(120000.0, 140000.0]	0	1	1	0	1
(140000.0, 160000.0]	0	0	0	0	1
(180000.0, 200000.0]	0	0	0	0	1
SS_VAL: How much did ... receive in social security payments during 20.. ?					
Universe: SS_YN = 1					
(-80.0, 8000.0]	14,729	27,315	9,197	5,611	79,192
(8000.0, 16000.0]	185	5,828	1,913	1,388	471
(16000.0, 24000.0]	91	3,923	2,002	1,553	335
(24000.0, 32000.0]	20	1,192	846	695	113
(32000.0, 40000.0]	2	203	146	140	21

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(40000.0, 48000.0]	8	279	136	107	30
(48000.0, 56000.0]	0	3	1	0	0
(56000.0, 64000.0]	0	0	0	1	1
(72000.0, 80000.0]	0	2	0	0	2
SS_YN: Who received social security payments either for themselves or as combined payments with other family members?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	397	13,477	5,642	4,471	1,228
No	12,207	15,101	7,111	3,864	61,308
SSI_VAL: How much did ... receive in supplemental security income during 20..?					
Universe: SSI_YN = 1					
(-50.0, 5000.0]	14,990	37,145	14,170	9,351	80,087
(5000.0, 10000.0]	35	1,032	35	77	47

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(10000.0, 15000.0]	3	388	21	44	21
(15000.0, 20000.0]	1	107	7	10	4
(20000.0, 25000.0]	2	41	3	9	3
(25000.0, 30000.0]	3	31	5	4	3
(45000.0, 50000.0]	1	1	0	0	0
SSI_YN: Did ... received ssi?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	59	2,241	101	192	110
No	12,545	26,337	12,652	8,143	62,426
STRKUC: At any time during 20.. did ... receive any union unemployment or strike benefits?					
Universe: UC_YN = 1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	4	10	3	4	27

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	12,600	28,568	12,750	8,331	62,509
SUBUC: At any time during 20.. did ... receive any supplemental unemployment benefits?					
Universe: UC_YN = 1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	11	28	9	8	47
No	12,593	28,550	12,744	8,327	62,489
SUR_SC1: What was the source of this other widow or survivor income?					
Universe: SUR_YN = 1					
None or niu	14,986	38,246	13,934	9,233	79,856
Company or union survivor pension	10	206	134	106	44
Federal government	7	49	25	41	26
Us military retirement survivor pension	2	48	10	10	9
State or local gov't survivor pension	3	44	34	39	19
Us railroad retirement survivor pension	2	14	6	3	5

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Worker compensation survivor	0	2	0	3	3
Black lung	0	1	0	0	1
Regular payments from estates or trusts	8	40	34	17	79
Regular payments from annuities or paid-up life insurance	6	29	30	15	42
Other or don't know	11	66	34	28	81
SUR_SC2: What was the source of this other widow or survivor income?					
Universe: SUR_YN = 1					
None or niu	15,034	38,731	14,233	9,490	80,152
Federal government	0	2	0	0	0
Us military retirement survivor pension	1	2	0	1	0
State or local gov't survivor pension	0	2	3	1	7
Worker compensation survivor	0	1	0	0	0
Black lung	0	0	0	1	0
Regular payments from estates or trusts	0	0	1	0	1
Regular payments from annuities or paid-up life insurance	0	5	1	2	0

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Other or don't know	0	2	3	0	5
SUR_VAL1: How much did ... receive (survivor source type) during 20.. ?					
Universe: SUR_YN = 1					
(-100.0, 10000.0]	15,009	38,539	14,106	9,366	80,014
(10000.0, 20000.0]	13	137	78	56	61
(20000.0, 30000.0]	6	35	25	36	32
(30000.0, 40000.0]	1	5	14	11	15
(40000.0, 50000.0]	3	14	5	10	6
(50000.0, 60000.0]	1	3	3	4	8
(60000.0, 70000.0]	0	0	1	1	7
(70000.0, 80000.0]	0	1	2	0	1
(90000.0, 100000.0]	2	11	7	11	21
SUR_VAL2: How much did ... receive (source type) during 20.. ?					
Universe: SUR_YN = 1					
(-100.0, 10000.0]	15,035	38,741	14,237	9,493	80,160

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(10000.0, 20000.0]	0	1	1	1	0
(20000.0, 30000.0]	0	0	0	0	1
(30000.0, 40000.0]	0	1	0	0	0
(60000.0, 70000.0]	0	1	1	1	0
(90000.0, 100000.0]	0	1	2	0	4
SUR_YN: During 20.. did ... receive any survivor benefits such as widow's pensions, estates, trusts, insurance annuities, or other survivor's income?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	49	499	307	262	309
No	12,555	28,079	12,446	8,073	62,227
TRDINT_VAL: Interest amount, exlcuding retirment account interest					
Universe: INT_YN = 1					
(-99.999, 9999.9]	15,018	38,629	14,089	9,398	79,874
(9999.9, 19999.8]	8	69	87	53	147

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(19999.8, 29999.7]	3	21	23	14	64
(29999.7, 39999.6]	2	8	16	8	24
(39999.6, 49999.5]	0	5	4	2	9
(49999.5, 59999.4]	1	6	6	4	14
(59999.4, 69999.3]	1	1	1	2	11
(69999.3, 79999.2]	1	1	3	4	7
(79999.2, 89999.1]	1	0	1	2	3
(89999.1, 99999.0]	0	5	11	8	12
UC_VAL: How much did ... receive in unemployment benefits during 20..?					
Universe: UC_YN = 1					
(-99.999, 9999.9]	15,013	38,710	14,224	9,465	80,074
(9999.9, 19999.8]	21	26	13	26	79
(19999.8, 29999.7]	1	6	0	1	5
(29999.7, 39999.6]	0	1	0	1	0
(39999.6, 49999.5]	0	1	1	0	4

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(49999.5, 59999.4]	0	1	3	2	1
(69999.3, 79999.2]	0	0	0	0	1
(89999.1, 99999.0]	0	0	0	0	1
UC_YN: Any type of unemployment compensation? (Combination of subuc, strkuc, and uctot_yn)					
Universe: UC_YN = 1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	180	305	119	154	805
No	12,424	28,273	12,634	8,181	61,731
VET_TYP1: What type of veterans payments did .... receive? (VET_TYP1-disability compensation?)					
Universe: VET_YN = 1					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	203	675	131	264	322

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
No	68	321	67	55	77
VET_TYP2: What type of veterans payments did .... receive? (VET_TYP2-survivor benefits?)					
Universe: VET_YN = 1					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	4	80	16	14	5
No	267	916	182	305	394
VET_TYP3: What type of veterans payments did .... receive? (VET_TYP3-veteran's pension?)					
Universe: VET_YN = 1					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	76	245	41	42	48
No	195	751	157	277	351
VET_TYP4: What type of veterans payments did .... receive? (VET_TYP4-education assistance?)					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: VET_YN = 1					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	14	18	3	7	24
No	257	978	195	312	375
VET_TYP5: What type of veterans payments did .... receive? (VET_TYP5- other veteran's payments?)					
Universe: VET_YN = 1					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	8	33	11	7	12
No	263	963	187	312	387
VET_VAL: How much did ... receive from veterans' administration during 20..?					
Universe: VET_YN = 1					
(-100.0, 10000.0]	14,845	38,124	14,132	9,317	79,960
(10000.0, 20000.0]	61	292	49	77	98

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(20000.0, 30000.0]	67	121	20	42	59
(30000.0, 40000.0]	23	134	24	34	25
(40000.0, 50000.0]	18	55	9	19	16
(50000.0, 60000.0]	3	8	2	2	1
(60000.0, 70000.0]	7	3	1	2	0
(70000.0, 80000.0]	4	0	1	0	0
(80000.0, 90000.0]	4	2	2	0	3
(90000.0, 100000.0]	3	6	1	2	3
VET_YN: Did ... receive veterans' payments?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	271	996	198	319	399
No	12,333	27,582	12,555	8,016	62,137
WC_TYPE: What was source of these payments?					
Universe: WC_YN = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Not in universe	14,980	38,653	14,204	9,447	79,891
State worker's compensation	15	40	14	15	74
Employer or employers insurance	39	42	23	30	187
Own insurance	0	1	0	0	5
Other	1	9	0	3	8
WC_VAL: How much compensation did ... receive during 20..?					
Universe: WC_YN = 1					
(-99.999, 9999.9]	15,009	38,712	14,227	9,467	80,086
(9999.9, 19999.8]	17	18	6	19	44
(19999.8, 29999.7]	5	8	2	2	15
(29999.7, 39999.6]	1	6	5	6	12
(39999.6, 49999.5]	0	0	0	0	3
(49999.5, 59999.4]	1	0	0	1	0
(59999.4, 69999.3]	0	1	0	0	3
(89999.1, 99999.0]	2	0	1	0	2

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
WC_YN: During 20.. did ... receive any worker's compensation payments or other payments as a result of a job related injury or illness?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	55	92	37	48	274
No	12,549	28,486	12,716	8,287	62,262
PAW_TYP: What type of program did... receive CASH assistance?					
Universe: PAW_YN = 1					
Niu	15,011	38,275	14,214	9,382	80,127
TANF/AFDC	14	327	13	51	16
Other	8	130	14	60	21
Both	2	13	0	2	1
PAW_VAL: How much did ... receive in public assistance or welfare during 20..?					
Universe: PAW_YN = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-25.0, 2500.0]	15,018	38,508	14,228	9,445	80,143
(2500.0, 5000.0]	6	115	7	28	8
(5000.0, 7500.0]	5	53	4	5	6
(7500.0, 10000.0]	2	42	1	8	3
(10000.0, 12500.0]	3	17	0	5	4
(12500.0, 15000.0]	1	6	0	0	0
(15000.0, 17500.0]	0	1	0	1	0
(17500.0, 20000.0]	0	0	0	2	1
(20000.0, 22500.0]	0	2	0	0	0
(22500.0, 25000.0]	0	1	1	1	0
PAW_YN: At any time during 20.., even for one month, did... receive an CASH assistance from a state or county welfare program such as (State program name fill)?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	24	470	27	113	38
No	12,580	28,108	12,726	8,222	62,498
PENINCL: Was ... included in that plan?					
Universe: PENPLAN = 1					
Niu	12,999	36,775	12,935	7,709	54,529
Yes	1,334	996	775	1,381	21,824
No	702	974	531	405	3,812
PENPLAN: Other than social security did the employer or union that ... worked for in 20.. have a pension or other type of retirement plan?					
Universe: WRK_CK = 1					
Niu	6,201	29,895	8,039	5,508	27,806
Yes	2,036	1,970	1,306	1,786	25,636
No	6,798	6,880	4,896	2,201	26,723
WICYN: Who received WIC?					
Universe: Adult female					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Niu	10,363	30,214	11,865	8,177	56,383
Received WIC	207	717	59	110	390
Did not receive WIC	4,465	7,814	2,317	1,208	23,392
CHCARE_YN: Paid child care was needed for this child?					
Universe: Persons age 15+ with children					
Niu	12,604	28,578	12,753	8,335	62,536
Yes	361	1,381	252	233	4,405
No	2,070	8,786	1,236	927	13,224
CHELSEW_YN: Does this person have a child living outside the household?					
Universe: All persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	386	443	163	129	1,438
No	12,218	28,135	12,590	8,206	61,098
CHSP_VAL: What is the annual amount of child support paid?					
Universe: CHSP_YN = 1					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-99.999, 9999.9]	15,003	38,723	14,222	9,484	79,970
(9999.9, 19999.8]	26	19	14	7	141
(19999.8, 29999.7]	4	1	1	2	41
(29999.7, 39999.6]	1	1	4	0	5
(39999.6, 49999.5]	1	0	0	1	2
(49999.5, 59999.4]	0	0	0	1	1
(59999.4, 69999.3]	0	1	0	0	1
(69999.3, 79999.2]	0	0	0	0	1
(89999.1, 99999.0]	0	0	0	0	3
CHSP_YN: Is this person required to pay child support?					
Universe: CHELSEW_YN					
Niu	14,649	38,302	14,078	9,366	78,727
Yes	194	136	70	41	681
No	192	307	93	88	757
CSP_VAL: How much did ... receive in child support payments?					

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: CHSP_YN = 1					
(-99.999, 9999.9]	15,010	38,682	14,215	9,484	79,977
(9999.9, 19999.8]	19	48	18	8	148
(19999.8, 29999.7]	5	10	5	1	23
(29999.7, 39999.6]	0	4	1	1	11
(39999.6, 49999.5]	1	0	1	1	2
(49999.5, 59999.4]	0	0	0	0	1
(69999.3, 79999.2]	0	0	1	0	0
(89999.1, 99999.0]	0	1	0	0	3
CSP_YN: Did ... receive child support payments?					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	201	560	112	136	1,080
No	12,403	28,018	12,641	8,199	61,456

ACTC_CRD: Additional child tax credit

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: Tax unit head or dependent filer					
(-11.1, 1110.0]	13,939	37,125	13,926	9,144	78,392
(1110.0, 2220.0]	534	804	153	168	833
(2220.0, 3330.0]	359	525	102	119	560
(3330.0, 4440.0]	153	215	45	42	256
(4440.0, 5550.0]	27	33	5	12	59
(5550.0, 6660.0]	17	29	8	8	41
(6660.0, 7770.0]	3	8	2	1	15
(7770.0, 8880.0]	2	4	0	0	4
(8880.0, 9990.0]	1	2	0	1	4
(9990.0, 11100.0]	0	0	0	0	1
AGI: Adjusted gross income					
Universe: Tax unit head or dependent filer					
(-12341.073, 224208.3]	14,924	38,542	13,917	9,179	77,141
(224208.3, 458415.6]	89	171	256	278	2,438

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(458415.6, 692622.9]	14	21	33	21	325
(692622.9, 926830.2]	4	5	16	4	98
(926830.2, 1161037.5]	4	5	11	9	87
(1161037.5, 1395244.8]	0	0	4	2	56
(1395244.8, 1629452.1]	0	1	1	2	7
(1629452.1, 1863659.4]	0	0	1	0	1
(1863659.4, 2097866.7]	0	0	1	0	6
(2097866.7, 2332074.0]	0	0	1	0	6
CTC_CRD: Child tax credit					
Universe: Tax unit head or dependent filer					
(-18.0, 1800.0]	13,956	38,047	13,477	8,913	69,728
(1800.0, 3600.0]	646	462	418	331	5,280
(3600.0, 5400.0]	327	186	250	182	3,845
(5400.0, 7200.0]	73	41	78	52	1,015
(7200.0, 9000.0]	26	8	15	15	236

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(9000.0, 10800.0]	5	1	2	2	40
(10800.0, 12600.0]	2	0	0	0	17
(12600.0, 14400.0]	0	0	0	0	2
(14400.0, 16200.0]	0	0	1	0	0
(16200.0, 18000.0]	0	0	0	0	2
EIT_CRED: Earn income tax credit					
Universe: Tax unit head or dependent filer					
(-6.557, 655.7]	13,787	36,710	13,872	9,134	78,356
(655.7, 1311.4]	106	159	45	40	348
(1311.4, 1967.1]	127	149	72	55	330
(1967.1, 2622.8]	153	229	44	46	281
(2622.8, 3278.5]	135	248	45	54	207
(3278.5, 3934.2]	263	420	62	60	266
(3934.2, 4589.9]	92	184	36	24	120
(4589.9, 5245.6]	88	152	20	26	86

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(5245.6, 5901.3]	168	306	28	39	117
(5901.3, 6557.0]	116	188	17	17	54
FED_RET: Federal retirement payroll deduction					
Universe: Tax unit head or dependent filer					
(-16.9, 1690.0]	15,032	38,744	14,241	9,491	80,153
(1690.0, 3380.0]	0	0	0	0	2
(3380.0, 5070.0]	1	1	0	0	2
(5070.0, 6760.0]	2	0	0	1	4
(6760.0, 8450.0]	0	0	0	0	1
(8450.0, 10140.0]	0	0	0	2	2
(10140.0, 11830.0]	0	0	0	0	1
(15210.0, 16900.0]	0	0	0	1	0
FEDTAX_AC: Federal income tax liability, after all credits					
Universe: Tax unit head or dependent filer					
(-10797.046, 69805.6]	15,001	38,684	14,139	9,415	79,276

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(69805.6, 149610.2]	22	49	66	62	605
(149610.2, 229414.8]	8	5	18	6	94
(229414.8, 309219.4]	2	3	7	4	62
(309219.4, 389024.0]	2	3	7	6	91
(389024.0, 468828.6]	0	1	1	2	23
(468828.6, 548633.2]	0	0	2	0	4
(628437.8, 708242.4]	0	0	1	0	6
(708242.4, 788047.0]	0	0	0	0	4
FEDTAX_BC: Federal income tax liability, before credits					
Universe: Tax unit head or dependent filer					
(-788.047, 78804.7]	15,006	38,696	14,150	9,434	79,411
(78804.7, 157609.4]	18	37	59	43	473
(157609.4, 236414.1]	7	5	14	6	96
(236414.1, 315218.8]	2	3	7	4	62
(315218.8, 394023.5]	2	3	7	6	90

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(394023.5, 472828.2]	0	1	1	2	19
(472828.2, 551632.9]	0	0	2	0	4
(630437.6, 709242.3]	0	0	1	0	6
(709242.3, 788047.0]	0	0	0	0	4
FICA: Social security retirement payroll deduction					
Universe: All persons					
(-55.449, 5544.9]	14,080	38,087	12,928	8,678	63,814
(5544.9, 11089.8]	821	521	979	661	14,090
(11089.8, 16634.7]	98	99	209	123	1,751
(16634.7, 22179.6]	23	29	85	19	287
(22179.6, 27724.5]	6	5	21	9	78
(27724.5, 33269.4]	5	4	13	5	134
(33269.4, 38814.3]	0	0	4	0	6
(38814.3, 44359.2]	1	0	2	0	1
(44359.2, 49904.1]	1	0	0	0	3

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(49904.1, 55449.0]	0	0	0	0	1
FILESTAT: Tax filer status					
Universe: All persons					
Joint, both<65	4,721	3,600	2,931	1,621	33,473
Joint, one ><65 & one 65+	235	1,045	692	782	1,812
Joint, both 65+	67	3,661	2,693	2,660	271
Head of household	764	1,485	350	299	3,024
Single	4,246	5,595	3,652	1,956	17,561
Non-filer	5,002	23,359	3,923	2,177	24,024
MARG_TAX: Marginal tax rate					
Universe: Tax unit head or dependent filer					
(-0.037, 3.7]	9,196	31,832	8,644	5,356	45,074
(7.4, 11.1]	1,801	2,645	1,229	717	3,139
(11.1, 14.8]	3,127	2,994	2,557	1,813	14,677
(18.5, 22.2]	687	920	1,267	1,088	11,655

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(22.2, 25.9]	174	259	404	403	4,335
(29.6, 33.3]	15	39	53	62	523
(33.3, 37.0]	35	56	87	56	762
PRSWKXPNS: Work expenses					
Universe: A_AGE > 17 or HHDFMX = 1,2,46, or 47					
(-2.065, 206.5]	6,481	30,475	8,279	5,658	29,096
(206.5, 413.0]	131	275	104	94	470
(413.0, 619.5]	175	312	141	101	591
(619.5, 826.0]	210	347	136	124	670
(826.0, 1032.5]	131	225	119	86	416
(1032.5, 1239.0]	352	504	210	178	879
(1239.0, 1445.5]	228	252	155	108	696
(1445.5, 1652.0]	292	336	238	161	1,100
(1652.0, 1858.5]	265	284	167	124	969
(1858.5, 2065.0]	6,770	5,735	4,692	2,861	45,278

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
STATETAX_A: State income tax liability, after all credits					
Universe: Tax unit head or dependent filer					
(-6490.585, 19727.5]	15,009	38,704	14,157	9,429	79,338
(19727.5, 45686.0]	20	37	63	54	637
(45686.0, 71644.5]	6	3	15	6	113
(71644.5, 97603.0]	0	0	2	6	35
(97603.0, 123561.5]	0	1	4	0	25
(123561.5, 149520.0]	0	0	0	0	10
(149520.0, 175478.5]	0	0	0	0	1
(175478.5, 201437.0]	0	0	0	0	3
(201437.0, 227395.5]	0	0	0	0	2
(227395.5, 253354.0]	0	0	0	0	1
STATETAX_B: State income tax liability, before credits					
Universe: Tax unit head or dependent filer					
(-253.354, 25335.4]	15,017	38,718	14,185	9,458	79,632

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(25335.4, 50670.8]	12	23	38	28	377
(50670.8, 76006.2]	6	3	12	4	83
(76006.2, 101341.6]	0	0	2	5	39
(101341.6, 126677.0]	0	1	4	0	18
(126677.0, 152012.4]	0	0	0	0	9
(152012.4, 177347.8]	0	0	0	0	1
(177347.8, 202683.2]	0	0	0	0	3
(202683.2, 228018.6]	0	0	0	0	2
(228018.6, 253354.0]	0	0	0	0	1
TAX_INC: Taxable income amount					
Universe: Tax unit head or dependent filer					
(-2298.214, 229821.4]	14,968	38,607	14,027	9,280	78,079
(229821.4, 459642.8]	49	112	153	185	1,604
(459642.8, 689464.2]	11	17	34	14	250
(689464.2, 919285.6]	5	4	10	4	78

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(919285.6, 1149107.0]	2	4	11	9	93
(1149107.0, 1378928.4]	0	1	3	3	45
(1378928.4, 1608749.8]	0	0	2	0	4
(1608749.8, 1838571.2]	0	0	0	0	1
(1838571.2, 2068392.6]	0	0	0	0	6
(2068392.6, 2298214.0]	0	0	1	0	5
PERLIS: Poverty level of persons (Subfamily members have primary family recode)					
Universe: All persons					
Not in poverty universe	29	173	9	37	46
Below poverty level	2,650	10,405	1,038	549	1,873
100 - 124 percent of the poverty level	872	3,558	448	302	898
125 - 149 percent of the poverty level	968	3,113	506	303	1,240
150 and above the poverty level	10,516	21,496	12,240	8,304	76,108

POV_UNIV: Poverty universe flag

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Universe: All persons					
Not in poverty universe	29	173	9	37	46
In poverty universe	15,006	38,572	14,232	9,458	80,119
HEA: Health status					
Universe: All persons					
Excellent	4,703	8,539	4,173	2,207	32,776
Very good	4,895	9,678	4,540	3,038	29,492
Good	4,164	11,856	3,859	2,899	15,028
Fair	1,039	6,158	1,247	1,007	2,439
Poor	234	2,514	422	344	430
SPM_ACTC: SPM units Additional Child Tax Credit					
Universe: All persons					
(-11.1, 1110.0]	11,509	28,742	13,080	8,266	72,935
(1110.0, 2220.0]	1,538	3,848	513	507	3,105
(2220.0, 3330.0]	1,172	3,423	362	420	2,227

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) (continued)

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(3330.0, 4440.0]	583	1,834	215	176	1,141
(4440.0, 5550.0]	111	393	26	55	337
(5550.0, 6660.0]	74	314	36	56	233
(6660.0, 7770.0]	25	111	9	2	116
(7770.0, 8880.0]	11	41	0	1	43
(8880.0, 9990.0]	9	32	0	12	15
(9990.0, 11100.0]	3	7	0	0	13

Code 3.8: Exploratory data analysis (describe.py)

```
import os
import pandas as pd
import warnings

from module.utility import create_dir, import_dict
from module.eda import *
from module.dataset import *
from cls.ThesisExtension import *

texlive_binpath = '/usr/local/texlive/2024/bin/x86_64-linux'
os.environ['PATH'] += os.pathsep + texlive_binpath

pd.set_option('display.max_columns', None)
pd.set_option('display.width', 1000)
warnings.filterwarnings('ignore')

# Given Information
dataset_name = "pppub20"

# Predefined Directories
meta_dir = "../../../Data/Original/metadata"
feather_dir = "../../../Data/Original/feather"
csv_dir = "../../../Data/Original/csv"

output_dir = f"../../../Outputs/Main/EDA/{dataset_name}"
log_dir = f"../../../Logs/preprocessing"
log_filepath = f"{log_dir}/describe.log"

backup_dir = "../../../Backups"

create_dir(log_dir)

```

```python
# Data Preparation
indep_dict = import_dict(metadatapath=f"{meta_dir}/meta-indep.json")
dep_attrs = ['GRP', 'DIR', 'PUB']
print()
describe_var(indep_dict)
print()
df = import_dataset(dataset_name=dataset_name, feather_dir=feather_dir)
print()
dep_features = ['class_orig', 'code_orig', 'code', 'class']
acpt_types = {'category', 'int16', 'int32', 'int8', 'uint16', 'uint32', 'uint8'}
preprocess = True

if all(feat in df.columns for feat in dep_features):
    col_types = set()
    for col in df.columns:
        col_types.add(str(df[col].dtype))
        if col_types == acpt_types:
            preprocess = False

if preprocess:
    df.thesis.code(indep_dict, dep_attrs)
    df.thesis.recode()

filepath_feather = f"{feather_dir}/{dataset_name}.feather"
filepath_csv = f"{csv_dir}/{dataset_name}.csv"

if not os.path.isfile(filepath_feather):
    export_dataset(df, file_dir='data/feather', dataset_name=dataset_name,
        format='feather')

if not os.path.isfile(filepath_csv):
    dfther = pd.read_feather(filepath_feather)
    export_dataset(dfther, file_dir='data/csv', dataset_name=dataset_name,
        format='csv')
```

```
# Univariate Data Analysis
df.thesis.show_type(option='full')
print()
df[['GRP','DIR','PUB','class_orig','code_orig','code','class']].
    drop_duplicates().sort_values('class').reset_index(drop=True)
print(f"Code: Employment-based plan (GRP) | Direct-purchase plan (DIR) |
    Public health insurance (PUB)")
print(df.groupby('code').size())
print('\n'*2)

# Cross Tabulation Analysis
print("----------------------------------------")
crosstab(df=df, indep_dict=indep_dict, cont_bins=10, plot=True, output_dir
    =output_dir, log_filepath=log_filepath, backup_dir=backup_dir)
```

3.5.7 Data Encoding

Code 3.9 encodes the input dataset in the correct format, zero for a continuous NIU (not in universe) value and 0 up to a positive integer for a categorical value, by instantiating the Data class defined in Code 3.6. The state of this instance is maintained by two attached atttributes `dataset`, a pandas DataFrame extended by the `data` accessor, and `metadata`, a Python list. The nonstatic methods `encodecat` and `encodecont` for encoding categorical and continuous features change the object into multiple states. This dissertation excessively uses the shallow copies of attributes by calling the method `copy` to protect the originals. Unlike a deep copy, a shallow copy inserts reference to an original object to the extent possible.

Code 3.9: Data encoding (convert.py)

```
import os
import pandas as pd
import pyarrow

from module.utility import create_dir, import_dict, export_json,
    export_txt
from module.metaencode import *
```

```python
from cls.Data import *

# Given Information
dataset_inname = "pppub20"
dataset_encname = f"{dataset_inname}enc"
dataset_procname = "proc20"

# Predefined Directories
meta_indir = "../../../Data/Original/metadata"
meta_extra_indir = f"{meta_indir}/extra"
feather_indir = "../../../Data/Original/feather"
csv_indir = "../../../Data/Original/csv"

meta_encdir = "../../../Data/Encoded/metadata"
meta_extra_encdir = f"{meta_encdir}/extra"
feather_encdir = "../../../Data/Encoded/feather"
csv_encdir = "../../../Data/Encoded/csv"
info_encdir = "../../../Data/Encoded/info"

csv_procdir = "../../../Data/Processed/csv"

create_dir(meta_extra_indir)
create_dir(feather_indir)
create_dir(csv_indir)
create_dir(meta_extra_encdir)
create_dir(feather_encdir)
create_dir(csv_encdir)
create_dir(info_encdir)
create_dir(csv_procdir)

# Metadata
indep_dict = import_dict(metadatapath=f"{meta_indir}/meta-indep.json")
export_json(extract_dict_cat(indep_dict), f"{meta_extra_indir}/meta-indep-
    cat.json")
export_json(extract_dict_cont(indep_dict), f"{meta_extra_indir}/meta-indep-
    cont.json")
```

```python

# Imported Dataset
if os.path.isfile(f"{feather_indir}/{dataset_inname}.feather"):
    df = pd.read_feather(f"{feather_indir}/{dataset_inname}.feather")
    if not os.path.isfile(f"{csv_indir}/{dataset_inname}.csv"):
        df.to_csv(f"{csv_indir}/{dataset_inname}.csv", index=False)
else:
    df = pd.read_csv(f"{csv_indir}/{dataset_inname}.csv")

# Encoded Dataset and Dictionary
data_obj = Data(df.copy(), indep_dict.copy())
cat_var_change = data_obj.encodecat()
cont_var_nonpos = data_obj.encodecont()
df_enc = data_obj.dataset
indep_dict_enc = data_obj.metadata

# Processed Dataset
dep_attrs = ['GRP', 'DIR', 'PUB']
class_attrs = ['class_orig','code_orig','code','class']
df_proc_enc = df_enc.drop(columns=['COV']+dep_attrs+class_attrs)
df_proc_enc = sort_cols(df_proc_enc, indep_dict_enc).join(df_enc['class'])
df_proc_info = indep_info(df_proc_enc.loc[:, df_proc_enc.columns != 'class'], indep_dict_enc)
df_count_info = count_info(df_proc_info)

# Exported Results
df_enc.to_feather(f"{feather_encdir}/{dataset_encname}.feather")
df_enc.to_csv(f"{csv_encdir}/{dataset_encname}.csv", index=False)
export_json(
    indep_dict_enc,
    f"{meta_encdir}/meta-indep-{dataset_encname}.json"
)
export_json(
    extract_dict_cat(indep_dict_enc),
    f"{meta_extra_encdir}/meta-indep-cat-{dataset_encname}.json"
)
```

```

df_proc_enc.to_csv(f"{csv_procdir}/{dataset_procname}.csv", header=True, index=False)

df_proc_info.index = df_proc_info.index + 1
df_proc_info.to_csv(f"{info_encdir}/{dataset_encname}-info.csv", index_label="id")
df_count_info.to_csv(f"{info_encdir}/{dataset_encname}-countinfo.csv", header=True, index=False)

export_txt(cat_var_change, f"{meta_extra_encdir}/catchange-{dataset_encname}.txt")
export_txt(cont_var_nonpos, f"{meta_extra_encdir}/contnonpos-{dataset_encname}.txt")
```

3.5.8 Sampling using SelectKBest

Because the classifier proposed in Chapter 4 is exponentially expensive, certain features are preselected by evaluating their scores against a target variable. Code 3.10 considers 3, 4 and 8 highest scores based on the mutual information for a discrete target. In addition, 100 out of 157,681 survey participants are sampled of equal class size by calling two methods `groupby` and `sample`. Due to its random nature, the sampling result changes in each call. The use of the model is illustrated in Chapter 5 with only three preselected features.

Code 3.10: SelectKBest (selectkbest.py)

```
import pandas as pd
from functools import partial
from sklearn.feature_selection import mutual_info_classif, SelectKBest

from module.utility import create_dir

sel_num_ls = [3, 4, 8]
train_eachclass_num = 20

```

```
data_filepath = "../../../Data/Processed/csv/proc20.csv"
info_filepath = "../../../Data/Encoded/info/pppub20enc-info.csv"

data_selname = "selproc20"
train_name = "seltrain20"
test_name = "seltest20"

# Predefined Directories
sample_dir = "../../../Samples/random"
sel_dir = f"{sample_dir}/{data_selname}"

data_dir = f"{sel_dir}/data"
info_dir = f"{sel_dir}/info"
feat_dir = f"{sel_dir}/features"
score_dir = f"{sel_dir}/scores"
train_dir = f"{sel_dir}/train"
test_dir = f"{sel_dir}/test"

create_dir(data_dir)
create_dir(info_dir)
create_dir(feat_dir)
create_dir(score_dir)
create_dir(train_dir)
create_dir(test_dir)

# Univariate Feature Selection
def feat_select(df_indata, df_info, sel_num):
    discrete_feat_idx = df_info.index[df_info['type']=='Categorical']
    score_func = partial(mutual_info_classif, discrete_features=
        discrete_feat_idx)
    feat_selector = SelectKBest(score_func, k=sel_num)
    feat_selector.fit(df_indata.drop('class', axis=1), df_indata['class'])

    df_scores = pd.DataFrame()
    df_scores["Attribute"] = df_indata.drop('class', axis=1).columns
    df_scores['Type'] = df_info['type']
```

```
    df_scores["Support"] = feat_selector.get_support()
    df_scores["F Score"] = feat_selector.scores_
    df_scores["P Value"] = feat_selector.pvalues_

    df_selfeat = df_scores[df_scores['Support']].drop('Support', axis=1).reset_index(drop=True)
    df_seldata = df_indata[df_selfeat['Attribute']].join(df_indata['class'])

    minmax = df_seldata.loc[:, df_seldata.columns != 'class'].agg(['min','max']).values.tolist()
    df_selfeat['Min'] = minmax[0]
    df_selfeat['Max'] = minmax[1]
    del minmax

    return df_seldata, df_selfeat, df_scores

# Implementation
df_indata = pd.read_csv(data_filepath)
df_info = pd.read_csv(info_filepath)

print(f"\n{df_indata.head()}\n")
print(f"{df_info.head()}\n")

for sel_num in sel_num_ls:

    # Univariate feature selection
    df_seldata, df_selfeat, df_scores = feat_select(df_indata=df_indata, df_info=df_info, sel_num=sel_num)

    # Display results (selected features)
    print(f"Select {sel_num} features:\n")
    print(f"{df_selfeat}\n")

    # Train-test split
    df_seltrain = df_seldata.groupby('class', group_keys=False).apply(
```

```
        lambda x: x.sample(train_eachclass_num)
    )
    df_seltest = df_seldata.drop(df_seltrain.index)

    # Exported results
    df_seldata.to_csv(f"{data_dir}/{data_selname}num{sel_num}.csv", header=True, index=False)

    df_selfeat.to_csv(f"{feat_dir}/fnum{sel_num}.csv", header=True, index=False)
    df_scores.to_csv(f"{score_dir}/snum{sel_num}.csv", header=True, index=False)

    df_selfeat.index = df_selfeat.index + 1
    df_selinfo = df_selfeat.drop(['F Score', 'P Value'], axis=1)
    df_selinfo.columns = ['variable', 'type', 'min', 'max']
    df_selinfo.to_csv(f"{info_dir}/{data_selname}num{sel_num}info.csv", index_label='id')

    df_seltrain.to_csv(f"{train_dir}/{train_name}num{sel_num}each{train_eachclass_num}.csv", header=True, index=False)
    df_seltest.to_csv(f"{test_dir}/{test_name}num{sel_num}exc{train_eachclass_num}.csv", header=True, index=False)
```

3.5.9 Setting Number of Variable Splits

Provided that two and three splits or cuts are of interest, Code 3.11 determines an appropriate number of splits on an individual feature in the health insurance dataset of all noninfant survey participants with full features and previously preselected 3, 4 and 8 features. For example, in the case of three splits, up to two splits are allowed on the feature SS_YN representing the answer, including NIU (not in universe), to the yes/no question regarding social security payments. The column of these numbers is inserted into the DataFrame as an additional information directly through the pandas accessor `info` in Code 3.7 without explicit class instantiation.

Code 3.11: Setting number of variable splits (setcut.py)

```python
import pandas as pd

from module.utility import create_dir
from cls.Info import *

# Given Information
pcut_ls = [2, 3]
info_ls = []
info_ls.append({
    'indir': "../../../Data/Encoded/info",
    'infile': "pppub20enc-info.csv",
    'outdir': "../../../Samples/proc20/cuts"
})
extra_infile_ls = [
    "selproc20num3info.csv",
    "selproc20num4info.csv",
    "selproc20num8info.csv"
]
for file in extra_infile_ls:
    info_ls.append({
        'indir': "../../../Samples/selproc20/info",
        'infile': file,
        'outdir': "../../../Samples/selproc20/cuts"
    })
print(f"\n{info_ls}\n")

# Implementation
for dc in info_ls:
    for pcut in pcut_ls:

        # Import
        inpath = f"{dc['indir']}/{dc['infile']}"
        df = pd.read_csv(inpath)

        # Set cuts
        pcont, pcatmax = pcut, pcut
```

```
    df.info.setcut(pcont, pcatmax)

    # Set output path
    infilename = dc['infile'].replace('.csv', '').replace('info', '').
        replace('-', '')
    cutfilename = f"{infilename}co{pcont}ca{pcatmax}cutinfo"
    outpath = f"{dc['outdir']}/{cutfilename}.csv"

    # Display results
    print(f"Input: {inpath}")
    print(f"NUmber of features: {len(df)}")
    print(f"Number of continuous cuts: {pcont}")
    print(f"Number of maximum categorical cuts: {pcatmax}")
    print(f"Output: {outpath}\n")
    print(f"{df.head()}\n")

    # Export
    create_dir(dc['outdir'])
    df.to_csv(outpath, header=True, index=False)
```

CHAPTER IV

PROPOSED CLASSIFIER

4.1 Proposed Model for Selecting Continuous Factors

Suppose a training dataset of dimension $\tilde{d}$ excluding its target variable has N instances, and every feature $1 \leq \tilde{j} \leq \tilde{d}$ is continuous. Each training instance $\tilde{x}^i = (\tilde{x}^i_{\tilde{j}})_{1 \leq \tilde{j} \leq \tilde{d}} \in \mathbb{R}^{\tilde{d}}$ where $1 \leq i \leq N$ has an integer class label between 0 and n. Let y^i_k specify whether a training instance $\tilde{x}^i$ is in class k for $0 \leq k \leq n$. Assume that at most $1 \leq d \leq \tilde{d}$ contributing factors are considered. It follows that a reduced instance $x^i = (x^i_j)_{1 \leq j \leq d} \in \mathbb{R}^d$ is a partial selection of the components of the original instance $\tilde{x}^i$:

$$
\begin{aligned}
x^i_j &= \sum_{j=1}^{d} c_{j,\tilde{j}} \tilde{x}^i_{\tilde{j}} \\
\sum_{\tilde{j}=1}^{\tilde{d}} c_{j,\tilde{j}} &\leq 1 \\
\sum_{j=1}^{d} c_{j,\tilde{j}} &\leq 1 \\
c_{j,\tilde{j}} &\in \{0, 1\}.
\end{aligned}
$$

An original feature $\tilde{j}$ is selected and considered significant when

$$\sum_{j=1}^{d} c_{j,\tilde{j}} = 1$$

and it becomes a new feature j, uniquely, for $c_{j,\tilde{j}} = 1$.

Every selected, rearranged feature $1 \leq j \leq d$ is assumed to have $p_j \geq 0$ splitting values: $b_{j,1} \leq \ldots \leq b_{j,p_j}$. Two endpoints are assumed: $b_{j,0} = -M$ and $b_{j,p_j+1} = M$ for sufficiently large positive M such as $\max\{|x^i_j|\}$. All splitting points along each new axis forms $B = (p_1 + 1) \cdots (p_d + 1)$ decision boxes. A box S_β is defined in the following manner:

$$S_\beta = \prod_{j=1}^{d} \sum_{q=0}^{p_j} \beta_{j,q} [b_{j,q}, b_{j,q+1}]$$

where $b_{j,0}$ and b_{j,p_j+1} are sufficiently small negative and large positive,

$$\beta = \sum_{j=1}^{d}\left[\prod_{j_0=0}^{j-1}(p_{j_0}+1)\right]\left[\sum_{q=0}^{p_j} q\beta_{j,q}\right]$$

$$\sum_{q=0}^{p_j}\beta_{j,q} = 1$$

$$\beta_{j,q} \in \{0,1\}$$

and $p_0 = 1$.

Each $x_j^i \in \mathbb{R}$ is in an open interval $(b_{j,q}, b_{j,q+1})$ for some $0 \le q \le p_j$, and its existence is indicated by a boolean variable $\alpha_{j,q}^i$:

$$\sum_{j=1}^{d} c_{j,\tilde{j}}\tilde{x}_{\tilde{j}}^i = x_j^i \in \sum_{q=0}^{p_j}\alpha_{j,q}^i[b_{j,q}+m_j, b_{j,q+1}-m_j] = \sum_{q=0}^{p_j}[l_{j,q}^i, r_{j,q}^i]$$

$$\sum_{q=0}^{p_j}\alpha_{j,q}^i = 1$$

$$\alpha_{j,q}^i \in \{0,1\}$$

for sufficiently small positive m_j such as

$$m_j = \frac{1}{2}\min\{|x_j^{i_1} - x_j^{i_2}| : x_j^{i_1} \neq x_j^{i_2}\}$$

and for some $l_{j,q}^i$ and $r_{j,q}^i$. Both terms are introduced to linearize the nonlinear products $\alpha_{j,q}^i(b_{j,q}+m_j)$ and $\alpha_{j,q}^i(b_{j,q+1}-m_j)$ respectively. Proven constructively, Theorem 4.1 ensures the linearizability.

Theorem 4.1. Two intervals $\alpha_{j,q}^i[b_{j,q}+m_j, b_{j,q+1}-m_j]$ and $[l_{j,q}^i, r_{j,q}^i]$ are identical only when

$$l_{j,q}^i \in [-M, b_{j,q}+m_j] + M(1-\alpha_{j,q}^i)$$

$$l_{j,q}^i \in [b_{j,q}+m_j, M] - M(1-\alpha_{j,q}^i)$$

$$r_{j,q}^i \in [-M, b_{j,q+1}-m_j] + M(1-\alpha_{j,q}^i)$$

$$r_{j,q}^i \in [b_{j,q+1}-m_j, M] - M(1-\alpha_{j,q}^i).$$

Proof. It suffices to show that $l^i_{j,q} = \alpha^i_{j,q}(b_{j,q} + m_j)$ under the given constraints because substitution $b_{j,q}$ and m_j with $b_{j,q+1}$ and $-m_j$ results in the expression for $r^i_{j,q}$. The equivalent condition for the nonlinear product is given by for sufficiently large positive M_1, M_2, M_3 and M_4

$$\begin{aligned} l^i_{j,q} &= \begin{cases} 0, & \text{for } \alpha^i_{j,q} = 0 \\ b_{j,q} + m_j, & \text{for } \alpha^i_{j,q} = 1 \end{cases} \\ &\in \begin{cases} [-M_1, 0] \cap [0, M_2], & \text{for } \alpha^i_{j,q} = 0 \\ [b_{j,q} + m_j, M_3] \cap [-M_4, b_{j,q} + m_j], & \text{for } \alpha^i_{j,q} = 1. \end{cases} \end{aligned}$$

Consider how each interval changes when $\alpha^i_{j,q}$ moves from 0 to 1:

$$[b_{j,q} + m_j, M_3] = [-M_1, 0] + [b_{j,q} + m_j + M_1, M_3]$$
$$[-M_4, b_{j,q} + m_j] = [0, M_2] + [-M_4, b_{j,q} + m_j - M_2].$$

Hence the translations are given by $(1 - \alpha^i_{j,q})[b_{j,q} + m_j + M_1, M_3]$ and $(1 - \alpha^i_{j,q})[-M_4, b_{j,q} + m_j - M_2]$. To remove all nonlinear terms, choose M_1 and M_2 such that $b_{j,q} + m_j + M_1$ and $b_{j,q} + m_j - M_2$ are constant. One example of such the ordered tuple (M_1, M_2, M_3, M_4) is $(M - b_{j,q} - m_j, M + b_{j,q} + m_j, M, M)$. $\square$

Governed by a boolean variable γ^i_β, an instance $x^i \in \mathbb{R}^d$ is also located in one of these boxes labeled by $0 \le \beta \le B - 1$:

$$\sum_{j=1}^{d} \left[\prod_{j_0=0}^{j-1} (p_{j_0} + 1) \right] \left[\sum_{q=0}^{p_j} q\alpha^i_{j,q} \right] = \sum_{\beta=0}^{B-1} \beta\gamma^i_\beta$$
$$\sum_{\beta=0}^{B-1} \gamma^i_\beta = 1$$
$$\gamma^i_\beta \in \{0, 1\}.$$

By majority voting, a decision box β therefore predicts exactly one class label from the following set

$$\Theta_\beta = \operatorname*{argmax}_{0 \le k \le n} \left\{ \sum_{i=1}^{N} y^i_k \gamma^i_\beta \right\}.$$

In total, there are

$$N - \sum_{\beta=0}^{B-1} \max_{0 \le k \le n} \left\{ \sum_{i=1}^{N} y^i_k \gamma^i_\beta \right\} = N + h_\beta$$

misclassified instances where

$$h_\beta = \min_{0 \le k \le n} \left\{ -\sum_{i=1}^{N} y^i_k \gamma^i_\beta \right\}.$$

Theorem 4.2. The optimal value of the program

$$
\begin{aligned}
\text{minimize} \quad & \sum_{\beta=0}^{B-1} h_\beta \\
\text{subject to} \quad & h_\beta + \sum_{i=1}^{N} y_k^i \gamma_\beta^i + N z_{\beta,k} \geq 0, \\
& \sum_{k=0}^{n} z_{\beta,k} = n, \\
& z_{\beta,k} \in \{0,1\}
\end{aligned}
$$

is given by

$$
\min_{0 \leq k \leq n} \left\{ -\sum_{i=1}^{N} y_k^i \gamma_\beta^i \right\}.
$$

Proof. Let $\mathcal{P}$ be the original problem. It can be partitioned into $n+1$ subproblems, each of which $\mathcal{P}_{k_0}$ for $0 \leq k_0 \leq n$ has the following restriction:

$$
z_{\beta,k} = \begin{cases} 0, & \text{for } k = k_0 \\ 1, & \text{for } k \neq k_0. \end{cases}
$$

For each subproblem $\mathcal{P}_{k_0}$,

$$
h_\beta \geq -\sum_{i=1}^{N} y_{k_0}^i \gamma_\beta^i = 0 - \sum_{i=1}^{N} y_{k_0}^i \gamma_\beta^i \geq -\sum_{i=1}^{N} y_k^i \gamma_\beta^i - N z_{\beta,k}
$$

and this implies

$$
\min(\mathcal{P}_{k_0}) = -\sum_{i=1}^{N} y_{k_0}^i \gamma_\beta^i.
$$

Hence

$$
\min(\mathcal{P}) = \min_{0 \leq k_0 \leq n} (\min(\mathcal{P}_{k_0})) = \min_{0 \leq k_0 \leq n} \left\{ -\sum_{i=1}^{N} y_{k_0}^i \gamma_\beta^i \right\}.
$$

□

By Theorems 4.1 and 4.2, the selection model for continuous dataset is given by

$$
\begin{aligned}
\text{minimize} \quad & \sum_{\beta=0}^{B-1} h_\beta \\
\text{subject to} \quad & \sum_{\tilde{j}=1}^{\tilde{d}} c_{j,\tilde{j}} \leq 1, \\
& \sum_{j=1}^{d} c_{j,\tilde{j}} \leq 1,
\end{aligned}
$$

$$
\begin{aligned}
b_{j,q+1} - b_{j,q} &\geq 0, \\
\sum_{j=1}^{d} \tilde{x}_{\tilde{j}}^{i} c_{j,\tilde{j}} - \sum_{q=0}^{p_j} l_{j,q}^{i} &\geq 0, \\
\sum_{j=1}^{d} \tilde{x}_{\tilde{j}}^{i} c_{j,\tilde{j}} - \sum_{q=0}^{p_j} r_{j,q}^{i} &\leq 0, \\
l_{j,q}^{i} + M\alpha_{j,q}^{i} &\geq 0, \\
l_{j,q}^{i} - M\alpha_{j,q}^{i} &\leq 0, \\
l_{j,q}^{i} - b_{j,q} + M\alpha_{j,q}^{i} &\leq M + m_j, \\
l_{j,q}^{i} - b_{j,q} - M\alpha_{j,q}^{i} &\geq -M + m_j, \\
r_{j,q}^{i} + M\alpha_{j,q}^{i} &\geq 0, \\
r_{j,q}^{i} - M\alpha_{j,q}^{i} &\leq 0, \\
r_{j,q}^{i} - b_{j,q+1} + M\alpha_{j,q}^{i} &\leq M - m_j, \\
r_{j,q}^{i} - b_{j,q+1} - M\alpha_{j,q}^{i} &\geq -M - m_j, \\
\sum_{j=1}^{d} \left[\prod_{j_0=0}^{j-1} (p_{j_0} + 1) \right] \left[\sum_{q=0}^{p_j} q\alpha_{j,q}^{i} \right] - \sum_{\beta=0}^{B-1} \beta\gamma_{\beta}^{i} &= 0, \\
\sum_{q=0}^{p_j} \alpha_{j,q}^{i} &= 1, \\
\sum_{\beta=0}^{B-1} \gamma_{\beta}^{i} &= 1, \\
h_{\beta} + \sum_{i=1}^{N} y_k^i \gamma_{\beta}^{i} + N z_{\beta,k} &\geq 0, \\
\sum_{k=0}^{n} z_{\beta,k} &= n, \\
l_{j,q}^{i}, r_{j,q}^{i}, b_{j,q}, h_{\beta} &\in \mathbb{R}, \\
c_{j,\tilde{j}}, \alpha_{j,q}^{i}, \gamma_{\beta}^{i}, z_{\beta,k} &\in \{0, 1\}
\end{aligned}
$$

where the artificial splitting values $b_{j,0}$ and b_{j,p_j+1} are also treated as decision variables, and it produces a training accuracy of

$$
1 + \frac{\sum_{\beta=0}^{B-1} h_{\beta}^{*}}{N} \leq 1.
$$

4.2 Selection of Mixed-Type Features

More generally, a training instance $\tilde{x}^i \in \mathbb{R}^{\tilde{d}}$ has a mixed-type component $\tilde{x}^i_{\tilde{j}} \in \mathbb{R}$ in feature $\tilde{j}$. The index sets of continuous and categorical features are denoted by $\tilde{\mathcal{C}}_{\text{cont}}$ and $\tilde{\mathcal{C}}_{\text{cat}}$ where

$$\tilde{\mathcal{C}}_{\text{cont}} \cup \tilde{\mathcal{C}}_{\text{cat}} = \{1, 2, \ldots, \tilde{d}\}.$$

The continuous features are initially selected, whereas all categorical features are kept. The latter will be subsequently selected. The sets $\mathcal{C}_{\text{cont}}$ and $\mathcal{C}_{\text{cat}}$ represent new continuous and intermediate categorical components respectively where

$$\begin{aligned} |\mathcal{C}_{\text{cont}}| &\leq |\tilde{\mathcal{C}}_{\text{cont}}| \\ |\mathcal{C}_{\text{cat}}| &= |\tilde{\mathcal{C}}_{\text{cat}}| \\ \mathcal{C}_{\text{cont}} \cup \mathcal{C}_{\text{cat}} &= \{1, 2, \ldots, d\}. \end{aligned}$$

These conditions above can be satisfied specifically, as illustrated on the health insurance dataset in Chapter 5, when $\mathcal{C}_{\text{cont}} \subseteq \tilde{\mathcal{C}}_{\text{cont}}$ and $\mathcal{C}_{\text{cat}} = \tilde{\mathcal{C}}_{\text{cat}}$, for instance. In the case of continuous data type, the constraints of feature selection become

$$\begin{aligned} x^i_j = \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} \tilde{x}^i_{\tilde{j}}, \qquad & j \in \mathcal{C}_{\text{cont}} \\ \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} \leq 1, \qquad & j \in \mathcal{C}_{\text{cont}} \\ \sum_{j \in \mathcal{C}_{\text{cont}}} c_{j,\tilde{j}} \leq 1, \qquad & \tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}} \\ c_{j,\tilde{j}} \in \{0, 1\}, \qquad & (j, \tilde{j}) \in \mathcal{C}_{\text{cont}} \times \mathcal{C}_{\text{cont}}. \end{aligned}$$

Since at most $|\mathcal{C}_{\text{cont}}|$ out of $|\tilde{\mathcal{C}}_{\text{cont}}|$ continuous features are selected, the following condition holds:

$$\sum_{(j,\tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} \leq |\mathcal{C}_{\text{cont}}|.$$

A selected, rearranged component $x^i_j \in \mathbb{R}$ for a feature $1 \leq j \leq d$ is now either continuous or categorical. A continuous feature $j \in \mathcal{C}_{\text{cont}}$ is similarly assumed to have p_j splitting points, namely $b_{j,q} \in \mathbb{R}$ where $1 \leq q \leq p_j$. Usually, p_j is assumed to be constant across all new continuous features because the new explicit order of this selection is unknown before optimization. A categorical feature $j \in \mathcal{C}_{\text{cat}}$ comprises finite discrete values which are also assumed to form $p_j + 1$ new small groups labeled with $0 \leq u_j \leq p_j$.

A box $0 \le \beta \le B-1$ along a categorical feature, as opposed to a continuous feature, lacks continuity because its entry is simply a singleton. Algebraically, it is represented by a set

$$S_\beta = \prod_{j \in \mathcal{C}_{\text{cont}}} \sum_{q=0}^{p_j} \beta_{j,q}[b_{j,q}, b_{j,q+1}] \times \prod_{j \in \mathcal{C}_{\text{cat}}} \{u_j\}$$

where

$$\begin{aligned}
\beta = \sum_{j \in \mathcal{C}_{\text{cont}}} &\left[\prod_{0 \le j_0 < j} (p_{j_0}+1)\right]\left[\sum_{q=0}^{p_j} q\beta_{j,q}\right] \\
&+ \sum_{j \in \mathcal{C}_{\text{cat}}} \left[\prod_{0 \le j_0 < j} (p_{j_0}+1)\right] u_j \\
\sum_{q=0}^{p_j} \beta_{j,q} = 1, &\qquad j \in \mathcal{C}_{\text{cont}} \\
\beta_{j,q} \in \{0,1\}, &\qquad j \in \mathcal{C}_{\text{cont}} \\
u_j \in \{0,1,\ldots,p_j\}, &\qquad j \in \mathcal{C}_{\text{cat}}
\end{aligned}$$

and $p_0 = 0$. The existence of $b_{j,0}$ and b_{j,p_j+1} where $j \in \mathcal{C}_{\text{cat}}$ is shown in the previous section. Numerically, each box can also be identified by the unique combination of binary $(\beta_{j,q})_{j \in \mathcal{C}_{\text{cont}}}$ and integer $(u_j)_{j \in \mathcal{C}_{\text{cat}}}$.

For a categorical feature $j \in \mathcal{C}_{\text{cat}}$, an original categorical label $x_j^i \in \mathbb{R}$ is reassigned to a new integer group label $0 \le v_{j,x_j^i} \le p_j$. As a result, the following conditions must hold:

$$\begin{aligned}
\sum_{\beta=0}^{B-1} \beta\gamma_\beta^i = \sum_{j \in \mathcal{C}_{\text{cont}}} &\left[\prod_{0 \le j_0 < j} (p_{j_0}+1)\right]\left[\sum_{q=0}^{p_j} q\alpha_{j,q}^i\right] \\
&+ \sum_{j \in \mathcal{C}_{\text{cat}}} \left[\prod_{0 \le j_0 < j} (p_{j_0}+1)\right] v_{j,x_j^i} \\
\sum_{q=0}^{p_j} \alpha_{j,q}^i = 1, &\qquad j \in \mathcal{C}_{\text{cont}} \\
\sum_{\beta=0}^{B-1} \gamma_\beta^i = 1, & \\
\beta_{j,q} \in \{0,1\}, &\qquad j \in \mathcal{C}_{\text{cont}} \\
v_{j,x_j^i} \in \{0,1,\ldots,p_j\}, &\qquad j \in \mathcal{C}_{\text{cat}}.
\end{aligned}$$

A boolean variable $f_j \in \{0,1\}$ is defined to determine whether a categorical feature j is significant. All categorical labels of an insignificant feature are grouped together. Its necessary, though insufficient, condition can be obtained:

$$-Mf_j \le v_{j,x_j^i} \le Mf_j.$$

If at most d_{cat} out of $|\mathcal{C}_{\text{cat}}|$ categorical features are of interest, the following condition holds:

$$\sum_{j \in \mathcal{C}_{\text{cat}}} f_j \le d_{\text{cat}}.$$

There are at most $|\mathcal{C}_{\text{cont}}| + d_{\text{cat}} \le d \le \tilde{d}$ contributing factors, $|\mathcal{C}_{\text{cont}}| \le |\tilde{\mathcal{C}}_{\text{cont}}|$ of which are continuous and $d_{\text{cat}} \le |\mathcal{C}_{\text{cat}}| = |\tilde{\mathcal{C}}_{\text{cat}}|$ categorical:

$$\sum_{(j,\tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} + \sum_{j \in \mathcal{C}_{\text{cat}}} f_j \le d.$$

An original feature $1 \le \tilde{j} \le \tilde{d}$ is deemed significant when

$$\sum_{j \in \mathcal{C}_{\text{cont}}} c_{j,\tilde{j}} = 1$$

for a continuous feature $\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}$, and a new group label v_{j,x^i_j} is nonconstant across all training instances x^i for a categorical feature $\tilde{j} \in \tilde{\mathcal{C}}_{\text{cat}}$ corresponding to $j \in \mathcal{C}_{\text{cat}}$. The condition $f_j = 0$ can also be used as an initial step to screen out an insignificant categorical feature $j \in \mathcal{C}_{\text{cat}}$.

The final selection model is proposed:

$$
\begin{aligned}
\text{minimize} \quad & \sum_{\beta=0}^{B-1} h_\beta \\
\text{subject to} \quad & \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} \le 1, && j \in \mathcal{C}_{\text{cont}}, \\
& \sum_{j \in \mathcal{C}_{\text{cont}}} c_{j,\tilde{j}} \le 1, && j \in \tilde{\mathcal{C}}_{\text{cont}}, \\
& b_{j,q+1} - b_{j,q} \ge 0, && j \in \mathcal{C}_{\text{cont}}, \\
& \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} \tilde{x}^i_{\tilde{j}} c_{j,\tilde{j}} - \sum_{q=0}^{p_j} l^i_{j,q} \ge 0, && j \in \mathcal{C}_{\text{cont}}, \\
& \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} \tilde{x}^i_{\tilde{j}} c_{j,\tilde{j}} - \sum_{q=0}^{p_j} r^i_{j,q} \le 0, && j \in \mathcal{C}_{\text{cont}}, \\
& l^i_{j,q} + M\alpha^i_{j,q} \ge 0, && j \in \mathcal{C}_{\text{cont}}, \\
& l^i_{j,q} - M\alpha^i_{j,q} \le 0, && j \in \mathcal{C}_{\text{cont}}, \\
& l^i_{j,q} - b_{j,q} + M\alpha^i_{j,q} \le M + m_j, && j \in \mathcal{C}_{\text{cont}}, \\
& l^i_{j,q} - b_{j,q} - M\alpha^i_{j,q} \ge -M + m_j, && j \in \mathcal{C}_{\text{cont}}, \\
& r^i_{j,q} + M\alpha^i_{j,q} \ge 0, && j \in \mathcal{C}_{\text{cont}}, \\
& r^i_{j,q} - M\alpha^i_{j,q} \le 0, && j \in \mathcal{C}_{\text{cont}},
\end{aligned}
$$

$$
\begin{aligned}
r^i_{j,q} - b_{j,q+1} + M\alpha^i_{j,q} &\leq M - m_j, && j \in \mathcal{C}_{\mathrm{cont}}, \\
r^i_{j,q} - b_{j,q+1} - M\alpha^i_{j,q} &\geq -M - m_j, && j \in \mathcal{C}_{\mathrm{cont}}, \\
\sum_{j \in \mathcal{C}_{\mathrm{cont}}} \left[\prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] \left[\sum_{q=0}^{p_j} q\alpha^i_{j,q} \right] & \\
+ \sum_{j \in \mathcal{C}_{\mathrm{cat}}} \left[\prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] v_{j,x^i_j} & \\
- \sum_{\beta=0}^{B-1} \beta\gamma^i_\beta &= 0, \\
\sum_{q=0}^{p_j} \alpha^i_{j,q} &= 1, && j \in \mathcal{C}_{\mathrm{cont}}, \\
v_{j,x^i_j} + M f_j &\geq 0, && j \in \mathcal{C}_{\mathrm{cat}}, \\
v_{j,x^i_j} - M f_j &\leq 0, && j \in \mathcal{C}_{\mathrm{cat}}, \\
\sum_{(j,\tilde{j}) \in \mathcal{C}_{\mathrm{cont}} \times \tilde{\mathcal{C}}_{\mathrm{cont}}} c_{j,\tilde{j}} + \sum_{j \in \mathcal{C}_{\mathrm{cat}}} f_j &\leq d, \\
\sum_{\beta=0}^{B-1} \gamma^i_\beta &= 1, \\
h_\beta + \sum_{i=1}^{N} y^i_k \gamma^i_\beta + N z_{\beta,k} &\geq 0, \\
\sum_{k=0}^{n} z_{\beta,k} &= n, \\
l^i_{j,q}, r^i_{j,q}, b_{j,q} &\in \mathbb{R}, && j \in \mathcal{C}_{\mathrm{cont}}, \\
h_\beta &\in \mathbb{R}, \\
c_{j,\tilde{j}} &\in \{0,1\}, && (j,\tilde{j}) \in \mathcal{C}_{\mathrm{cont}} \times \tilde{\mathcal{C}}_{\mathrm{cont}}, \\
\alpha^i_{j,q} &\in \{0,1\}, && j \in \mathcal{C}_{\mathrm{cont}}, \\
f_j &\in \{0,1\}, && j \in \mathcal{C}_{\mathrm{cat}}, \\
v_{j,x^i_j} &\in \{0,1,\ldots,p_j\}, && j \in \mathcal{C}_{\mathrm{cat}}, \\
\alpha^i_{j,q}, \gamma^i_\beta, z_{\beta,k} &\in \{0,1\}.
\end{aligned}
$$

4.3 CPLEX OPL Modeling

The proposed classifier heavily relies on 0-1 mixed integer programming (MIP). The CPLEX optimizer (version 22.1.1) is used to solve for the classifier including its splitting values and the set of predicted class labels in each decision box. Although achieving higher performance, manual adjustment of internal optimization procedures such as a node selection during branching and a combination of multiple techniques in cut generation is beyond the scope of this dissertation. The MIP problem is very large, and its information is stored in a huge tree data structure. Multiple lock-free nodes can be executed simultaneously in parallel by utilizing all available CPU cores. CPLEX uses in-memory computation.

When a central memory is consumed more than its upper limit which is 2048 MB by default, some nodes are transferred from the in-memory set to node files which are in memory and compressed by default. Optionally, they can be flushed to disk, in either uncompressed or compressed form, where speed is sacrificed for more storage space. As more solutions are explored, the branch-and-cut tree grows larger. When its size exceeds its upper limit, which is set at 10^{75} MB by default, the optimization process terminates. The solver also stops when a memory is exhausted or a disk is fully occupied depending on whether node files are stored in memory or on disk. CPLEX parameters related to this dissertation is included in Table 4.1.

Table 4.1: Relevant CPLEX parameters

Parameter	Description
`cplex.intsollim`	MIP solution number limit
`cplex.tilim`	Time limit per optimizer call (in seconds)
`cplex.threads`	Parallel threads (default: 0 implying up to 32 threads)
`cplex.workmem`	Working memory before compression and swap (in MB) (default: 2048)
`cplex.trelim`	Uncompressed tree limit (in MB) (default: 10^{75})
`cplex.nodefileind`	Node storage file switch 0: No node file 1: Node file in memory and compressed (default) 2: Node file on disk 3: Node file on disk and compressed
`cplex.status`	Solution status code 1: Optimal for simplex and barrier methods

Table 4.1: Relevant CPLEX parameters (continued)

Parameter	Description
	11: Time limit exceeded
	101: Optimal for MIP model
	102: Optimal within predefined MIP gap tolerance
	104: Limit on mixed integer solutions
	111: Tree memory limit exceeded and integer solution found
	112: Tree memory limit exceeded and no integer solution

Two following classification files are written in Optimization Programming Language (OPL), supported by default. Code 4.1 is the main execution of the classification model in Code 4.2. Two data structures are employed: an array and a tuple. Once the first is declared, its size is unchanged. The latter is used as a secondary option only when a combination of indexes cannot perfectly fit in an array format. As illustrated in Chapter 5, only three features are considered: A_AGE, PEMLR and SS_YN. Three splits are assumed except two for SS_YN representing both whether social security payments are paid and whether a survey participant is in the universe of this question. Two most significant factors are of interest. The cardinality of a new continuous component $|\mathcal{C}_{\text{cont}}|$ is assumed to be the minimum of its given counterpart $|\tilde{\mathcal{C}}_{\text{cont}}| = 1$ and an upper bound on the number of significant features $d = 2$. The continuous feature selection can be partially concluded by the condition $c^*_{j,\tilde{j}} = 1$. The sufficiently small positive number m_0 is set to be 0.01. The execution time is limited up to 24 hours or one day. Code 4.1 records every MIP solution, feasible but not necessarily optimal, thereby calling a CPLEX solver multiple times. After the working memory exceeds 2 GB, some nodes are transferred to disk in compressed form. The uncompressed tree size is limited to 200 GB.

Code 4.1: Main OPL model

```
/*********************************************
 * OPL 22.1.1.0 Model
 * Author: songkomkrit
 * Creation Date: Nov 4, 2024 at 12:24:05 AM
 *********************************************/

```

```
/*********************************************
 * NOTES
 * pl.bc.solutionValue[thisOplModel.mPairs.find(1,0)]
 *********************************************/

/*********************************************
 * Class Labels
 * Input file: 0, 1, 2, ..., n
 * Algorithm: 0, 1, 2, ..., n
 * Output file: 0, 1, 2, ..., n
 *********************************************/

/*********************************************
 * INPUTS
 *********************************************/
int mdimold = 3; // dimension   // 4 or 184 or 8 or 4
int mdimcontold = 1; // continuous dimension // 2 or 66 or 3 or 2
//int mdimcat = 2; // categorical dimension // 2 or 118 or 5 or 2
int mN = 100; // number of instances // 8 or 157681 or 100 or 100
int mn = 4;  // the value of n = (number of classes) - 1  // 1 or 4 or 4

int mseltol = 2; // given number of total selected cont/cat dimensions (at most)

// Initialized UB on number of selected continuous dimensions
int mselcont = mdimcontold;
execute {
    if (mselcont > mseltol)
        mselcont = mseltol;
}

int mexccont = mdimcontold - mselcont; // computed LB on number of excluded continuous dimensions
int mdim = mdimold - mexccont;
int mdimcont = mselcont;

```

```
range mDS = 1..mdim;
range mDSCONTOLD = 1..mdimcontold; // old continuous
range mDSCONT = 1..mselcont; // new continuous
range mDSCAT = mdimcont+1..mdim; // shifted categorical
range mIS = 1..mN;
float mxcontold[mIS][mDSCONTOLD]; // x along continuous dimensions
int mxcat[mIS][mDSCAT]; // x along categorical dimensions
int my[mIS];
int mmaxlab[mDSCAT]; // maximum labels for categorical dimensions
float mM[mDS]; // big-M for all new/shifted dimensions (continuous and categorical)
float mm[mDSCONT]; // small-m for continuous dimensions
int mp[mDS]; // number of cuts along axes
int mcoef[mDS];

/**********************************************
 * TUPLES
 **********************************************/
tuple ContPairType { // index for continuous cut
    int j;
    int q;
};

{ContPairType} mContPairs = {<j, q> | j in mDSCONT, q in 0..mp[j]+1};

tuple ContTripleType { // index for continuous cut of each individual instance
    int i;
    int j;
    int q;
};

{ContTripleType} mContTriples = {<i, j, q> | i in mIS, j in mDSCONT, q in 0..mp[j]};

tuple CatPairType { // index for categorical group
```

```
    int j;
    int l;
};

{CatPairType} mCatPairs = {<j, l> | j in mDSCAT, l in 0..mmaxlab[j]};

tuple tuplePred {
    key int b;
    sorted {int} label;
}
sorted {tuplePred} mpred;
{int} memptyset = {};

/*********************************************
 * OUTSIDE EXECUTION
 *********************************************/
execute {
    thisOplModel.settings.run_engineLog = "tmp/current-engine.log"; // temporary engine log
}

/*********************************************
 * MAIN EXECUTION
 *********************************************/
main {
    var ftime = Opl.round((new Date()).getTime()/1000) % 100000; // first timestamp (in seconds)

    // Input/variable filenames
    var infilename = "input/seltrain20num3each20.csv";   // input filename
    var varfilename = "input/selproc20num3co3ca3cutinfo.csv"; // variable filename (6 columns)

    // Prefix of all output files
    var prefixout = "output/" + ftime + "-";
    prefixout += infilename.split("/")[1].split(".")[0] + "-";
```

```

// Inputs
//var M0 = 500;   // big-M (float)
var m0 = 0.01;   // small-m (float)
var pcont0 = 3;   // max number of cuts along continuous axis (integer)

// Customization
var timelimit = 1; // whether set total time limits (1 = limit / 0 = none)
var limit = 1;  // whether customize performance settings (1 = customize / 0 = none)
var perf = 1;  // whether set limits (1 = limit / 0 = none)

// Custom time limit parameter
if (timelimit == 1)
    var acctimelimmin = 24*60; // accumulated time limit (in minutes)

// Cplex limit parameters (excluding time limit)
if (limit == 1) {
    var intsollim = 1; // MIP solution number limit (in each iteration)
}

// Cplex performance parameters
if (perf == 1) {
    var threads = 0; // parallel threads (default: 0 = at most 32 threads)
    var workmemgb = 2; // working memory before compression and swap (in GB) (default: 2 GB) (only marginally improved efficiency)
    var trelimgb = 200; // uncompressed tree memory limit (in GB) (default: around 1e+72 GB)

    /* Node storage file switch
     * 0 = No node file
     * 1 = Node file in memory and compressed (default)
     * 2 = Node file on disk
     * 3 = Node file on disk and compressed
```

```
         */
        var nodefileind = 3;

        /* Note on directory for temporary working files
         * cplex.workdir = ...;
         * CPLEX Error 1422: Could not open file for writing
         */

        // Calculation
        var workmem = 1024*workmemgb; // working memory before compression and swap (in MB) (default: 2048 MB)
        var trelim = 1024*trelimgb;  // uncompressed tree memory limit (in MB) (default: 1e+75 MB)
    }

    // Postfixes
    var cpostfixname = "mfullaltseltol-" + thisOplModel.mseltol; // common postfix name
    if (timelimit == 1)
        cpostfixname += "-t-" + acctimelimmin + ".csv";
    else
        cpostfixname += ".csv";
    var postfixerror = "-" + cpostfixname; // postfix of error file
    var postfixout = "-pcont-" + pcont0 + "-" + cpostfixname; // postfix of all other output files

    // Output filenames
    var outerrorname = prefixout + "export-error" + postfixerror;
    var outinstancename = prefixout + "export-predict-instance" + postfixout;
    var outcutcontname = prefixout + "export-cutcont-full" + postfixout;
    var outcutcatname = prefixout + "export-cutcat-full" + postfixout;
    // The existence of region is not checked here
    // In fact, it can be check through enumeration of certain binary representations
    var outregionname = prefixout + "export-predict-region" + postfixout;
```

```
var outselvarintname = prefixout + "export-select-var-int" + postfixout; // selected variables (integer)
var outselvarstrname = prefixout + "export-select-var-str" + postfixout; // selected variables (string)

// Engine log (initialized)
var logfilename = "log/" + ftime + "-engine-" + cpostfixname.split(".")[0] + ".log";
var outlog = new IloOplOutputFile(logfilename);

// OPL
var source = new IloOplModelSource("p-mixed-cuts-alt-seltol.mod");
var cplex = new IloCplex();
var def = new IloOplModelDefinition(source);
var opl = new IloOplModel(def,cplex);
var data = new IloOplDataElements();

data.dimold = thisOplModel.mdimold;
data.dimcontold = thisOplModel.mdimcontold;
data.dim = thisOplModel.mdim;
data.dimcont = thisOplModel.mdimcont;
//data.dimcat = thisOplModel.mdimcat;
data.N = thisOplModel.mN;
data.n = thisOplModel.mn;
data.xcontold = thisOplModel.mxcontold;
data.xcat = thisOplModel.mxcat;
data.y = thisOplModel.my;

var pred = thisOplModel.mpred;  // set of predicted labels

data.seltol = thisOplModel.mseltol;
data.selcont = thisOplModel.mselcont;
data.exccont = thisOplModel.mexccont;

data.m = thisOplModel.mm;
for (var j=1; j<=data.dimcont; j++)
```

```
        data.m[j] = m0;

    var f = new IloOplInputFile(infilename); // training dataset
    f.readline();        // skip a header
    for (var i=1; i<=data.N; i++) {
        var myitem = f.readline().split(",");
        data.y[i] = Opl.intValue(myitem[data.dimold]);
        for (var j=1; j<=data.dimcontold; j++)
            data.xcontold[i][j] = Opl.floatValue(myitem[j-1]);
        for (var j=data.dimcontold+1; j<=data.dimold; j++)
            data.xcat[i][j-data.exccont] = Opl.intValue(myitem[j-1]);
    }
    f.close();

    data.p = thisOplModel.mp;
    for (var j=1; j<=data.dimcont; j++)
        data.p[j] = pcont0;

    data.M = thisOplModel.mM;
    data.maxlab = thisOplModel.mmaxlab;
    var M0cont = 1;
    var f = new IloOplInputFile(varfilename); // variable info
    f.readline();        // skip a header
    for (var j=1; j<=data.dimold; j++) {
        var myitem = f.readline().split(",");
        if (j <= data.dimcontold) {
            var curMcont = 1 + Opl.maxl(Opl.abs(Opl.intValue(myitem[3])),
                Opl.abs(Opl.intValue(myitem[4])));
            M0cont = Opl.maxl(M0cont, curMcont);
        }
        else {
            data.p[j-data.exccont] = Opl.intValue(myitem[5]);
            data.maxlab[j-data.exccont] = Opl.intValue(myitem[4]);
            data.M[j-data.exccont] = 1 + Opl.intValue(myitem[5]);
        }
    }
```

```
f.close();

for (var j=1; j<=data.dimcont; j++)
    data.M[j] = M0cont;

data.coef = thisOplModel.mcoef;
data.coef[1] = 1;
for (var j=2; j<=data.dim; j++)
    data.coef[j] = data.coef[j-1]*(data.p[j]+1);

var nump = 0;  // total number of cuts
for (var j=1; j<=data.dim; j++)
    nump += data.p[j];

opl.addDataSource(data);
opl.generate();
opl.settings.mainEndEnabled = true;

// Cplex limits (excluding time limit)
if (limit == 1) {
    cplex.intsollim = intsollim; // MIP solution number limit (> 0)
}

// Cplex performance
if (perf == 1) {
    cplex.threads = threads; // parallel threads
    cplex.workmem = workmem; // working memory before compression and swap (in MB)
    cplex.trelim = trelim;  // uncompressed tree memory limit (in MB)
    cplex.nodefileind = nodefileind; // node storage file switch
}

// Initialization
var status = -9; // solution status code (initialized)
var iter = 0;  // iteration
var acctime = 0; // accumulated running time (in seconds)
```

```
var texceed = 0; // whether acctime > tilimmin (1 = total time limit exceeded / 0 = not)

// Calculation
if (timelimit == 1)
    var acctimelim = 60*acctimelimmin; // accumulated time limit (in seconds)
else
    var acctimelim = -1;

// Optimization
while (texceed == 0) { // accumulated time limit not exceeded

    // Exit status codes
    if (status == 1)  // 1: CPX_STAT_OPTIMAL
        break;
    else if (status == 101) // 101: CPXMIP_OPTIMAL
        break;
    else if (status == 102) // 102: CPXMIP_OPTIMAL_TOL
        break;
    else if (status == 111) // 111: CPXMIP_MEM_LIM_FEAS
        break;
    else if (status == 112) // 112: CPXMIP_MEM_LIM_INFEAS
        break;

    /* Non-exit status codes
     * 11: CPX_STAT_ABORT_TIME_LIM
     * 104: CPXMIP_SOL_LIM
     */

    // In the case when the previous status is not one of the above
    if (timelimit == 1)   // time limit for each call to optimizer (in seconds)
        cplex.tilim = acctimelim - acctime;
    var start = new Date();  // begin a timer

```

```
        pred.clear(); // clear previous set of predicted labels

        // Solve
        if (cplex.solve()) {

            var end = new Date(); // end a timer
            var solvetime = end.getTime() - start.getTime(); // compute solving time
            acctime += solvetime/1000; // accumulated running time (in s)

            if ((timelimit == 1) && (acctime >= acctimelim)) // total time limit exceeded (in seconds)
                texceed = 1;

            iter += 1; // update iteration

            var error = data.N + cplex.getObjValue(); // the number of misclassified instances
            var accuracy = (1-error/data.N)*100; // training accuracy

            status = cplex.status; // solution status code (1 = opt / 11 = time limit / ...)
            var lberr = data.N + cplex.getBestObjValue(); // LB on minimum (optimal) error
            var relgap = cplex.getMIPRelativeGap(); // relative objective gap for MIP

            // Open output text files (append = true)
            var outerror = new IloOplOutputFile(outerrorname, true);
            var outinstance = new IloOplOutputFile(outinstancename, true);
            var outcutcont = new IloOplOutputFile(outcutcontname, true);
            var outcutcat = new IloOplOutputFile(outcutcatname, true);
            var outregion = new IloOplOutputFile(outregionname, true);
            var outselvarint = new IloOplOutputFile(outselvarintname, true);
```

```
        var outselvarstr = new IloOplOutputFile(outselvarstrname, true);

        // outerror
        if (!outerror.exists) {
            outerror.write("iter,");
            for (var j=1; j<=data.dim; j++)
                outerror.write("p", j, ",");
            outerror.write("error,accuracy,ms,acctmin,status,lberr,
                relgap");
        }
        outerror.write("\n", iter, ",");
        for (var j=1; j<=data.dim; j++)
            outerror.write(data.p[j], ",");
        outerror.write(error, ",", accuracy, ",");
        outerror.write(solvetime, ",", acctime/60, ",");
        outerror.write(status, ",", lberr, ",", relgap);

        // Scripting logs 1
        writeln("\n-----------------------------");
        writeln("Iteration ", iter);
        writeln("Bounds on # of cuts = ", nump, " with", data.p);
        writeln("Error = ", error, " (out of ", data.N, " instances)");
        writeln("Accuracy = ", accuracy);
        writeln("Solving time = ", solvetime/60000, " min (minutes)");
        writeln("Accumulated time = ", acctime/60, " min (minutes)");
        writeln("\nSolution status code = ", status);
        writeln("LB on error = ", lberr);
        writeln("Relative objective gap = ", relgap);
        writeln("\nSelected variables:");

        // Create a set of predicted labels (majority voting)
        for (var b=0; b<opl.B; b++) {
            var lset = Opl.operatorUNION(thisOplModel.memptyset,
                thisOplModel.memptyset);
            var maxnum = 0;
```

```
    for (var k=0; k<=data.n; k++) {
        var num = 0;
        for (var i=1; i<=data.N; i++)
            num += (data.y[i] == k)*opl.g.solutionValue[i][b];

        if (num == maxnum)
            lset.add(k);
        else if (num > maxnum) {
            maxnum = num;
            lset.clear();
            lset.add(k);
        }
    }
    pred.add(b, lset);
}

// outinstance
if (!outinstance.exists)
    outinstance.write("iter,id,class,region,predict");
for (var i=1; i<=data.N; i++) {
    outinstance.write("\n", iter, ",", i, ",", data.y[i], ",");
    for (var b=0; b<opl.B; b++)
        if (opl.g.solutionValue[i][b] == 1) { // occur only once
            outinstance.write(b, ",");
            outinstance.write(pred.get(b).label);
            break; // terminate the loop
        }
}

// outcutcont
if (!outcutcont.exists)
    outcutcont.write("iter,j,q,bc");
for (var j=1; j<=data.dimcont; j++) {
    for (var q=1; q<=data.p[j]; q++) {
        outcutcont.write("\n", iter, ",", j, ",", q, ",");
```

```
        outcutcont.write(opl.bc.solutionValue[thisOplModel.mContPairs.find(j,q)]);
    }
}

// outcutcat
if (!outcutcat.exists)
    outcutcat.write("iter,j,l,v");
for (var j=data.dimcont+1; j<=data.dim; j++) {
    for (var l=0; l<=data.maxlab[j]; l++) {
        outcutcat.write("\n", iter, ",", j, ",", l, ",");
        outcutcat.write(opl.v.solutionValue[thisOplModel.mCatPairs.find(j,l)]);
    }
}

// outregion
if (!outregion.exists)
    outregion.write("iter,region,occupy,predict");
for (var b=0; b<opl.B; b++) {
    outregion.write("\n", iter, ",", b, ",");
    var s = 0;  // initialize s (presumably unoccupied)
    for (var i=1; i<=data.N; i++)
        if (opl.g.solutionValue[i][b] == 1) { // occupied
            s = 1;
            break; // iterminate the loop
        }
    outregion.write(s, ",");
    outregion.write(pred.get(b).label);
}

// outselvarint
if (!outselvarint.exists)
    outselvarint.write("iter,j,jold,mselect,type"); // mselect = model select (not actual)
```

```
for (var j=1; j<=data.dimcont; j++) { // selected continuous features
    outselvarint.write("\n", iter, ",", j, ",");
    var seljold = -1;
    for (var jold=1; jold<=data.dimcontold; jold++)
        // Determine which old continuous feature is selected
        if (opl.ccont.solutionValue[j][jold] == 1) {
            seljold = jold;
            break; // terminate the loop
        }
    outselvarint.write(seljold, ",");
    outselvarint.write("1,"); // Based on model, all new cont features are selected
    outselvarint.write("cont");
}
for (var j=data.dimcont+1; j<=data.dim; j++) { // categorical feature
    outselvarint.write("\n", iter, ",", j, ",", j+data.exccont, ",");
    if (opl.f.solutionValue[j] == 1) // selected categorical feature (model)
        outselvarint.write("1,");
    else // unselected categorical feature (model)
        outselvarint.write("0,");
    outselvarint.write("cat");
}

// outselvarstr
if (!outselvarstr.exists)
    outselvarstr.write("iter,jold,jnew,aselect,type,variable"); // aselect = actual select
var varinfile = new IloOplInputFile(varfilename);  // variable info
varinfile.readline(); // skip a header
var numselcont = 0; // initialized number of actually selected continuous features
```

```
var numselcat = 0; // initialized number of actually selected categorical features
for (var jold=1; jold<=data.dimcontold; jold++) { // CONTINUOUS
    outselvarstr.write("\n", iter, ",", jold, ",");
    var jnew = -1;
    var aselect = 0; // initialized to be unselected (continuous)
    for (var j=1; j<=data.dimcont; j++)
        // Determine whether a current old continuous feature is selected
        if (opl.ccont.solutionValue[j][jold] == 1) { // selected (actual 1/2)
            jnew = j;
            break; // terminate the loop
        }
    outselvarstr.write(jnew, ",");
    var myitem = varinfile.readline().split(",");
    if (jnew > 0) { // selected continuous feature (actual 1/2)
        aselect = 1; // seem to be selected (initialization for actual 2/2)
        for (var q=0; q<=data.p[jnew]; q++) {
            var bcleft = opl.bc.solutionValue[thisOplModel.mContPairs.find(jnew,q)];
            var bcright = opl.bc.solutionValue[thisOplModel.mContPairs.find(jnew,q+1)];
            var minxjnew = Opl.intValue(myitem[3]);
            var maxxjnew = Opl.intValue(myitem[4]);
            if ((bcleft <= minxjnew) && (bcright >= maxxjnew)) { // cover [min,max]
                aselect = 0; // unselected (actual 2/2)
                break;
            }
        }
    }
    outselvarstr.write(aselect, ",");
    if (aselect == 1) { // actually selected continuous feature
```

```
            // Scripting logs 2 (continuous)
            write("\t", myitem[1], " (Continuous)\n");
            numselcont += 1;
        }
        outselvarstr.write("cont,");
        outselvarstr.write(myitem[1]); // variable name
    }
    for (var jold=data.dimcontold+1; jold<=data.dimold; jold++) { // CATEGORICAL
        var jnew = jold-data.exccont;
        outselvarstr.write("\n", iter, ",", jold, ",", jnew, ",");
        var aselect = 0; // initialized to be unselected (categorical)
        var myitem = varinfile.readline().split(",");
        if (opl.f.solutionValue[jnew] == 1) { // selected categorical feature (actual 1/2)
            var vat0 = opl.v.solutionValue[thisOplModel.mCatPairs.find(jnew,0)];
            for (var l=1; l<=data.maxlab[jnew]; l++) {
                var vcur = opl.v.solutionValue[thisOplModel.mCatPairs.find(jnew,l)];
                if (vcur != vat0) { // distinct new groups are detected
                    aselect = 1; // selected categorical feature (actual 2/2)
                    break;
                }
            }
        }
        outselvarstr.write(aselect, ",");
        if (aselect == 1) { // actually selected categorical feature
            // Scripting logs 2 (categorical)
            write("\t", myitem[1], " (Categorical)\n");
            numselcat += 1;
        }
        outselvarstr.write("cat,");
```

```
            outselvarstr.write(myitem[1]);
        }
        varinfile.close();

        // Scripting logs 3
        var numselall = numselcont + numselcat;
        writeln("\nNumber of selected variables = ", numselall, " (",
            numselcont, " continuous + ", numselcat, " categorical)");
        writeln("------------------------------");

        // Closing output text files
        outerror.close();
        outinstance.close();
        outcutcont.close();
        outcutcat.close();
        outregion.close();
        outselvarint.close();
        outselvarstr.close();
    }
    else
        writeln("No solution");
}

opl.end();
data.end();
def.end();
cplex.end();
source.end();

// Engine log (exported)
var inlog = new IloOplInputFile("tmp/current-engine.log");
while (!inlog.eof) {
    outlog.writeln(inlog.readline());
}
inlog.close();
outlog.close();
```

```
}
```

Code 4.2: Box classifier OPL model

```
/*********************************************
 * OPL 22.1.1.0 Model
 * Author: songkomkrit
 * Creation Date: Nov 4, 2024 at 1:15:57 AM
 *********************************************/

/*********************************************
 * DATA INFORMATION (INPUTS)
 *********************************************/
int dimold = ...; // old dimension
int dimcontold = ...; // old continuous dimension
int dim = ...; // new dimension
int dimcont = ...; // new continuous dimension
//int dimcat = ...; // categorical dimension
int N = ...; // number of instances
int n = ...; // number of classes

/*********************************************
 * FEATURE SELECTION (INPUTS)
 *********************************************/
int seltol = ...; // given number of total selected cont/cat dimensions (at most)
int selcont = ...; // UB on number of selected continuous dimensions
int exccont = ...; // computed LB on number of excluded continuous dimensions

/*********************************************
 * INDEX RANGES 1
 *********************************************/
range DS = 1..dim;  // for dimensions
range DSCONTOLD = 1..dimcontold; // for old continuous dimensions
```

```
range DSCONT = 1..dimcont; // for new continuous dimensions
range DSCAT = dimcont+1..dim; // for shifted categorical dimensions
range IS = 1..N;  // for instances
range KS = 0..n;  // for classes

/*********************************************
 * INITIAL PARAMETERS (INPUTS)
 *********************************************/
float M[DS] = ...;  // big-M for all new/shifted dimensions (continuous
    and categorical)
float m[DSCONT] = ...; // small-m for new continuous dimensions

/*********************************************
 * DATA EXTRACTION (INPUTS)
 *********************************************/
float xcontold[IS][DSCONTOLD] = ...; // instances along old continuous
    dimensions
int xcat[IS][DSCAT] = ...; // instances along shifted categorical
    dimensions
int y[IS] = ...;  // targets
int maxlab[DSCAT] = ...;  // maximum labels for new categorical dimensions
int p[DS] = ...;  // number of cuts along axes
int coef[DS] = ...;  // product coefficients

/*********************************************
 * NUMBER OF BOXES
 *********************************************/
int B = 1;    // initialize the number of boxes
execute {
    for (var j in DS)
        B = B*(p[j]+1); // compute the number of boxes
}

/*********************************************
 * INDEX RANGES 2
 *********************************************/
```

```
range BS = 0..B-1;  // for regions

/*********************************************
 * TUPLES
 *********************************************/
tuple ContPairType { // index for continuous cut
    int j;
    int q;
};

{ContPairType} ContPairs = {<j, q> | j in DSCONT, q in 0..p[j]+1};

tuple ContTripleType { // index for continuous cut of each individual instance
    int i;
    int j;
    int q;
};

{ContTripleType} ContTriples = {<i, j, q> | i in IS, j in DSCONT, q in 0..p[j]};

tuple CatPairType { // index for categorical group
    int j;
    int l;
};

{CatPairType} CatPairs = {<j, l> | j in DSCAT, l in 0..maxlab[j]};

/*********************************************
 * DECISION VARIABLES
 *********************************************/
dvar float l[ContTriples];
dvar float r[ContTriples];
dvar float bc[ContPairs];  // bc is in R (c = cut)
// Note that b is used for beta indexing
```

```
dvar float h[BS];   // h
dvar boolean a[ContTriples]; // alpha
dvar int+ v[CatPairs]; // v (categorical features)
dvar boolean g[IS][BS];  // gamma
dvar boolean z[BS][KS];  //
// Feature selection
dvar boolean ccont[DSCONT][DSCONTOLD]; // select continuous dimensions
dvar boolean f[DSCAT];    // select categorical dimensions

/*********************************************
 * OBJECTIVE FUNCTION
 *********************************************/
minimize sum(b in BS) h[b];   // min total number of misclassifed
    instances

/*********************************************
 * CONSTRAINTS
 *********************************************/
subject to {

    forall(j in DSCONT)
        getnewcont:
            sum(jold in DSCONTOLD) ccont[j][jold] <= 1;

    forall(jold in DSCONTOLD)
        seloldcont:
            sum(j in DSCONT) ccont[j][jold] <= 1;

    forall(j in DSCONT, q in 0..p[j])
        bc[<j,q+1>] - bc[<j,q>] >= 0;

    forall(i in IS, j in DSCONT) {
        lbound:
            (sum(jold in DSCONTOLD) xcontold[i][jold]*ccont[j][jold]) - (
                sum(q in 0..p[j]) l[<i,j,q>]) >= 0;
        rbound:
```

```
            (sum(jold in DSCONTOLD) xcontold[i][jold]*ccont[j][jold]) - (
              sum(q in 0..p[j]) r[<i,j,q>]) <= 0;
    }

    forall(i in IS, j in DSCONT, q in 0..p[j]) {
        l[<i,j,q>] + M[j]*a[<i,j,q>] >= 0;
        l[<i,j,q>] - M[j]*a[<i,j,q>] <= 0;
        l[<i,j,q>] - bc[<j,q>] + M[j]*a[<i,j,q>] <= M[j] + m[j];
        l[<i,j,q>] - bc[<j,q>] - M[j]*a[<i,j,q>] >= -M[j] + m[j];
        r[<i,j,q>] + M[j]*a[<i,j,q>] >= 0;
        r[<i,j,q>] - M[j]*a[<i,j,q>] <= 0;
        r[<i,j,q>] - bc[<j,q+1>] + M[j]*a[<i,j,q>] <= M[j] - m[j];
        r[<i,j,q>] - bc[<j,q+1>] - M[j]*a[<i,j,q>] >= -M[j] - m[j];
    }

    forall(i in IS)
        (sum(j in DSCONT) coef[j]*(sum(q in 0..p[j]) q*a[<i,j,q>])) + (sum(
          j in DSCAT) coef[j]*v[<j,xcat[i][j]>]) - (sum(b in BS) b*g[i][b
          ]) == 0;

    forall(i in IS, j in DSCONT)
        pregion:
            sum(q in 0..p[j]) a[<i,j,q>] == 1;

    forall(i in IS) {
        bregion:
            sum(b in BS) g[i][b] == 1;
    }

    forall(b in BS, k in KS)
        error1:
            h[b] + (sum(i in IS) (y[i] == k)*g[i][b]) + N*z[b][k] >= 0;

    forall(b in BS)
        error2:
            sum(k in KS) z[b][k] == n;
```

```

    forall(j in DSCAT, l in 0..maxlab[j])
        v[<j,l>] <= p[j];

    forall(i in IS, j in DSCAT) {
        selcat1:
            v[<j,xcat[i][j]>] + M[j]*f[j] >= 0;
        selcat2:
            v[<j,xcat[i][j]>] - M[j]*f[j] <= 0;
    }

    seltolnum:
        (sum(j in DSCONT, jold in DSCONTOLD) ccont[j][jold]) + (sum(j in
            DSCAT) f[j]) <= seltol;
}
```

4.4 Recalculation of Decision Boxes

Some of selected d features may be trivial; therefore, they cannot be contributing factors. This occurs when two consecutive splitting values along a continuous feature covers an entire dataset or all categorical values are reallocated to the same group. Moreover, no continuous feature may be actually selected ($c^*_{j,\tilde{j}} = 0$), but the proposed classification model usually assumes that there are up to d new continuous features ($|\mathcal{C}_{\text{cont}}| \leq d$). All of these circumstances lead to excessive number of decision boxes. A close examination of optimal splitting values $b^*_{j,q}$ and v^*_{j,x^i_j} can further provide which feature is actually important and should be finally selected, thereby reducing number of boxes. To determine which two distinct boxes can be merged, all numerical decision box labels are recalculated through a transformation g to new labels in a final feature space.

Suppose only d' out of d features are finally selected. The feature map $\sigma : \{0, 1, \ldots, d\} \to \{-1\} \cup \{0, 1, \ldots, d'\}$ is defined by

$$\sigma(j) = \begin{cases} \text{feature in new space,} & \text{for finally selected feature } j \\ -1, & \text{for finally unselected feature } j \\ 0, & \text{if } j = 0. \end{cases}$$

There is a one-to-one corresponding between j and $\sigma(j) \geq 0$, and the image of σ includes $0, 1, \ldots, d'$. Consider a decision box $1 \leq \beta \leq B$. Define its position along a feature j by

$$q_j = \begin{cases} \sum_{q=0}^{p_j} q\beta_{j,q}, & \text{for continuous feature } j \\ u_j, & \text{for categorical feature } j. \end{cases}$$

Let $w = \min\{j : q_j \neq 0\}$. If $w = 1$, then both positions of the current box β and the previous counterpart $\beta - 1$ along the first feature differ by 1. For $w > 1$, the previous box $\beta - 1$ locates at position p_j along every feature $j < w$, and the position of both boxes at feature w differs by 1. Based on this observation, the following recurrence relation of new box labels can be obtained:

$$g(\beta) - g(\beta - 1) = -\sum_{j=1}^{w-1} p_j \prod_{j' \in \Sigma_j} (p_{j'} + 1) + 1 \cdot \prod_{j' \in \Sigma_w} (p_{j'} + 1)$$

where $\Sigma_j = \{j' : 0 \leq \sigma(j') < \sigma(j)\}$.

The utility module in Code 4.3 includes file copying, floating point number rounding, retrieving all keys of maximum dictionary value, finding an interval containing a given number, and exporting DataFrame with nonduplicate entries. The typecasting module in Code 4.4 can convert a set in string format to a Python set and vice versa, and also express an immutable interval object in string format. The recalculation module in Code 4.5 computes a full list of final numerical decision regions $g(\beta)$. Modules 4.6 and 4.7 returns the dictionaries of selected features and their splitting values respectively. True decision regions including their predicted class labels are computed by Module 4.8. Similar results generated by Module 4.9 is based solely on numerical decision regions, possibly redundant before merging, and their predicted class labels directly reported by CPLEX optimizer. As shown in Chapter 5, CPLEX solutions are inconsistent and therefore infeasible during first few iterations. Module 4.10 calculates the number of correctly classified instances based on the true decision region from Module 4.8 and the CPLEX counterpart from Module 4.9. Clearly, the first is more accurate than the latter. Code 4.11 is the main execution file. A DataFrame iterator initially constructed by the method `itertuples` is utilized only when a DataFrame, an iterable, can be iterated row by row using the method `next` during an informational query; nonetheless, its usage is not recommended when a query answer is scattered over rows.

Code 4.3: Basic utility for recalculation of region (module/operation/xutil.py)

```
import os
```

```python
import shutil
import json
import math
import numpy as np
import pandas as pd

# Create directory (if not exist)
def create_dir(dir):
    '''
        Usage: create directory (if not exist)
        Required arguments:
            dir: directory name
    '''

    try: os.makedirs(dir)
    except FileExistsError: pass


# Copy single file
def copy(srcpath, destpath):
    '''
        Usage: copy single file
        Required arguments:
            srcpath: source pathname
            destpath: destination pathname
    '''

    # Split path into directory and file
    srcdir, srcfile = os.path.split(srcpath) # source
    destdir, destfile = os.path.split(destpath) # destination

    # Create destination directory (if not exist)
    create_dir(destdir)

    # Copy source file into destination folder (filename unchanged)
    shutil.copy2(srcpath, destdir) # preserve file metadata
```

```python

    # Rename copied file to correct destination filename
    os.rename(f"{destdir}/{srcfile}", destpath)


# Round up or down number to decimal places
def round_num(number, decimals, direction):
    '''
        Usage: round up or down number to decimal places
        Required arguments:
            number: number to be rounded
            decimals: number of decimal places to round to
            direction: either up or down ('up', 'down')
        Outputs:
            rounded number to specified decimal places
    '''

    if isinstance(decimals, int) or isinstance(decimals, np.integer):
        if decimals >= 0:
            if direction == 'up':
                return math.ceil(number*10**decimals)/10**decimals
            elif direction == 'down':
                return math.floor(number*10**decimals)/10**decimals
            else:
                raise TypeError("Direction can be either up or down")
        else:
            raise TypeError("Number of decimal places to round to must be
                nonnegative")
    else:
        raise TypeError("Number of decimal places must be an integer")


# Find maximum value of dictionary and key set
def max_dictval(dc):
    '''
```

```
        Usage: find maximum value of dictionary and all of its corresponding keys
        Required arguments:
            dc: dictionary
        Outputs:
            kmax: set of all keys of maximum value
            vmax: maximum value
    '''

    kmax = set()
    vmax = dc[next(iter(dc))] # value of first key
    for k, v in dc.items():
        if v > vmax:
            vmax = v
            kmax = {k}
        elif v == vmax:
            kmax.add(k)

    return kmax, vmax


# Find interval index of specific value from list of real-line splits
def itvpos(x, splits, closed='neither'):
    '''
        Usage: find interval index of specific value from array of real-line splits
        Required arguments:
            x: specific value of interest
            splits: list of real line splits
            closed: whether intervals are closed on left-side, right-side or neither ('left', 'right', 'neither')
        Outputs:
            interval index of specific input value
    '''

    if closed == 'left': # [_, s), [s, _)
```

```
        for i, s in enumerate(splits):
            if x < s: return i
    elif closed == 'neither': # (_, s), (s, _)
        for s in splits:
            if x == s:
                raise Exception(f"Open intervals are chosen but input value {x} is at split value {s}")
        closed = 'right' # now safe to be extended to (_, s], (s, _]

    if closed == 'right': # (_, s], (s, _]
        for i, s in enumerate(splits):
            if x <= s:
                return i

    # Last interval
    return i + 1


# Return left and right endpoints of rounded interval
def itvtopts(itv, decimals=2, extend=True):
    '''
        Usage: return left and right endpoints of rounded interval
        Required arguments:
            itv: Pandas interval to be rounded
        Optional arguments:
            decimals: number of decimal places to round to (default: 2)
            extend: whether extend (true) or shrink (default) interval (default: True)
        Outputs:
            lpt: left endpoint of rounded interval
            rpt: right endpoint of rounded interval
    '''

    if isinstance(itv, pd._libs.interval.Interval):
        if extend:
            ldirect, rdirect = 'down', 'up'
```

```
        else:
            ldirect, rdirect = 'up', 'down'

        if np.isinf(itv.left):
            lpt = itv.left
        else:
            lpt = round_num(itv.left, decimals, ldirect)

        if np.isinf(itv.right):
            rpt = itv.right
        else:
            rpt = round_num(itv.right, decimals, rdirect)

        return lpt, rpt

    else:
        raise TypeError("Only Pandas intervals are allowed")


# Import dictionary from JSON file
def import_dict(jsonpath):
    '''
        Usage: parse JSON data into dictionary
        Required arguments:
            jsonpath: JSON filepath (usually metadata filepath)
        Outputs:
            dictionary
    '''

    with open(jsonpath) as file:
        contents = file.read()

    # JSON data is parsed into dictionary
    return json.loads(contents)
```

```python
# Export dataframe with nonduplicate entries
def nondup(df, ndcols, intcols=list(), intdtype='Int16'):
    '''
        Usage: export dataframe with nonduplicate entries
        Required arguments:
            df: dataframe
            ndcols: two-dimensional multilevel column lists with nonduplicate entries
        Optional arguments:
            intcols: integer columns (default: empty list)
            intdtype: Pandas integer data type (default: 'Int16' or pd.Int16Dtype())
        Outputs: same dataframe but without duplicate entries
    '''

    dfn = df.copy(deep=True)
    for i in range(len(ndcols),0,-1): # iterate over multilevel column lists with nonduplicate entries
        ccols = [f for cols in ndcols[0:i] for f in cols]
        dfn.loc[dfn[ccols].duplicated(), ccols] = pd.NA
    for col in intcols:
        dfn[col] = pd.array(dfn[col], dtype=intdtype)

    return dfn
```

Code 4.4: Typecasting (module/operation/typecast.py)

```python
import numpy as np
import pandas as pd

from module.operation.xutil import itvtopts


# Convert set/number in string format to Python set
def strtoset(setstr):
```

```
    '''
        Usage: convert set/number in string format to Python set
        Required arguments:
            setstr: set/number in string format
        Outputs: corresponding set
    '''

    strset = set(setstr.strip().strip('{ }'))
    try: strset.remove(' ') # for set of more than two elements
    except: pass
    numset = set(map(int, strset))

    return numset


# Convert set to string
def settostr(st, sep=',', left='{', right='}'):
    '''
        Usage: convert set to string
        Required arguments:
            st: set
        Optional arguments:
            sep: separator (default: ',')
            left: left symbol (default: '{')
            right: right symbol (default: '}')
        Outputs: string representing given set
    '''

    stre = sep.join([str(e) for e in st])

    return f"{left}{stre}{right}"


# Convert Pandas interval to string
def itvtostr(itv, decimals=2, extend=True):
    '''
```

```
        Usage: convert Pandas interval to string
        Required arguments:
            itv: Pandas interval
        Optional arguments:
            decimals: number of decimal places to round to (default: 2)
            extend: whether extend (true) or shrink (default) interval (default: True)
        Outputs: string interval
    '''

    lpt, rpt = itvtopts(itv, decimals, extend)
    l = f"{lpt:.{decimals}f}"
    r = f"{rpt:.{decimals}f}"

    if itv.closed == 'neither': return f"({l}, {r})"
    elif itv.closed == 'left': return f"[{l}, {r})"
    elif itv.closed == 'right': return f"({l}, {r}]"
    else: return f"[{l}, {r}]"


# Describe Pandas interval in text format
def itvtodesc(itv, decimals=2, extend=True):
    '''
        Usage: describe Pandas interval in text format
        Required arguments:
            itv: Pandas interval
        Optional arguments:
            decimals: number of decimal places to round to (default: 2)
            extend: whether extend (true) or shrink (default) interval (default: True)
        Outputs: description of interval in text format
    '''

    lpt, rpt = itvtopts(itv, decimals, extend)
    l = f"{lpt:.{decimals}f}"
    r = f"{rpt:.{decimals}f}"
```

```
    esum = itv.left + itv.right
    if np.isnan(esum): # -np.inf, np.inf
        return "any number"
    elif not np.isinf(esum): # num, num
        return f"between {l} and {r}"
    elif esum < 0: # -np.inf, num
        return f"below {r}"
    else: # num, np.inf
        return f"above {l}"
```

Code 4.5: Recalculation of regions (module/operation/calregs.py)

```
import numpy as np


# Calculate new corresponding region label (helper)
def hcalbn(bo, bnprev, idxn, pcuto, pocum, pncumx):
    '''
        Usage: calculate new corresponding region label (helper)
        Required arguments:
            bo: region label for old features (nonzero)
            bnprev: previous region label for new features
            idxn: new feature indexes
            pcuto: old cut numbers
            pocum: cumulative number of box regions across old features
            pncumx: cumulative number of extrended box regions across new
                features
        Outputs: corresponding region label
    '''

    # bo must be between 1 and np.prod(pcuto+1)-1
    bn = bnprev
    for jmax in range(len(pcuto)-1,-1,-1):
```

```
        # bo (incremented by 1) in base representation has the last nonzero at digit jmax
        if bo%pocum[jmax] == 0:
            for j in range(jmax):
                bn -= pcuto[j]*pncumx[idxn[j]]
            bn += pncumx[idxn[jmax]]
            break

    return bn


# Calculate corresponding decision regions (helper)
def hcalregs(BO, idxn, pcuto, pocum, pncumx):
    '''
        Usage: calculate corresponding decision regions (helper)
        Required arguments:
            BO: total number of old box regions
            idxn: new feature indexes
            pcuto: old cut numbers
            pocum: cumulative number of box regions across old features
            pncumx: cumulative number of extrended box regions across new features
        Outputs: corresponding region label
    '''

    bns = [0] # list of corresponding box regions (region 0)
    for bo in range(1, BO):
        bnprev = bns[-1]
        bn = hcalbn(bo, bnprev, idxn, pcuto, pocum, pncumx)
        bns.append(bn)

    return bns


# Calculate new corresponding decision regions (main)
```

```
def calregs(pcuto, sidx, pdtype=np.int16, idtype=np.int16, rdtype=np.int16):
    '''
        Usage: calculate new corresponding decision regions (main)
        Required arguments:
            pcuto: old cut numbers
            sidx: selected feature indexes (in order)
        Optional arguments:
            pdtype: NumPy data type of cut number (default: np.int16)
            idtype: NumPy data type of index (default: np.int16)
            rdtype: NumPy data type of region number (default: np.int16)
        Outputs: new correspoding regions
    '''

    # Typecasting
    pcuto = np.array(pcuto, dtype=pdtype)
    sidx = np.array(sidx, dtype=idtype)

    # Basic calculation
    dimo = pcuto.size # old dimension
    dimn = sidx.size # new dimension
    pcutn = pcuto[sidx] # new cut numbers
    BO = np.prod(pcuto+1).astype(rdtype) # number of old regions
    BN = np.prod(pcutn+1).astype(rdtype) # number of new regions

    # New feature indexes
    idxn = np.full(dimo, -1, dtype=idtype)
    idxn[sidx] = np.arange(dimn, dtype=idtype)
    idxn[idxn < 0] = np.arange(dimn, dimo, dtype=idtype)

    # Cumulative number of box regions
    pocum = np.cumprod(np.append([1], pcuto[0:-1]+1), dtype=rdtype) # old
    pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=rdtype) # new
    pncumx = np.concatenate((pncum, np.zeros(dimo-dimn, dtype=rdtype))) # new and extended

```

```
    # New correspoding regions (helper function called)
    bns = np.array(hcalregs(B0, idxn, pcuto, pocum, pncumx), dtype=rdtype)

    # Output
    return bns


# Illustration
'''
print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0],
    calregs(pcuto, sidx)))
print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1],
    calregs(pcuto, sidx)))
print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0,
    1], calregs(pcuto, sidx)))
print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1,
    0], calregs(pcuto, sidx)))
'''
```

Code 4.6: Feature selection (module/model/findsels.py)

```
# Find feature selection
def findsels(itsel, pcuto):
    '''
        Usage: find feature selection (per file)
        Required arguments:
            itsel: selected string variables (DataFrame iterator)
            pcuto: old cut numbers
        Outputs:
            tsels: dictionary of selected variables and given number of
                cuts
    '''

    csrow = next(itsel) # iterator of selected string variables across all
        iterations
```

```
    tsels = dict() # selected variables and given number of cuts

    citer = -1 # current iteration
    while True:
        try:
            if csrow.aselect == 1: # for selected variable
                if csrow.iter != citer:
                    citer = csrow.iter
                    tsels[citer] = {
                        'variables': list(), # selected feature
                        'types': list(), # type of selected feature
                        'js': list(), # selected index
                        'ps': list() # given cut number
                    }
                tsels[citer]['variables'].append(csrow.variable)
                tsels[citer]['types'].append(csrow.type)
                tsels[citer]['js'].append(csrow.jnew)
                tsels[citer]['ps'].append(pcuto[csrow.jnew-1])
            csrow = next(itsel) # update DataFrame iterator
        except StopIteration:
            break

    return tsels
```

Code 4.7: Cuts or split values (module/model/findcuts.py)

```
import numpy as np
import pandas as pd

# Find cuts and groups
def findcuts(tsels, itcont, itcat, intvclosed='neither', intvsubtype='float32'):
    '''
        Usage: find cuts and groups (per file)
        Required arguments:
```

```
        tsels: dictionary of selected variables and given number of
            cuts
        itcont: full continuous cuts (DataFrame iterator)
        itcat: full categiorical cuts (DataFrame iterator)
    Optional arguments:
        intvclosed: types of Pandas interval sides (values: 'left', '
            right', 'both', 'neither')
        intvsubtype: types of Pandas interval bounds (subtype of pandas.
            IntervalDtype)
    Outputs:
        tcuts: dictionary of cuts and groups along all selected
            features
'''

ccontrow = next(itcont) # iterator of full continuous cuts across all
    iterations
ccatrow = next(itcat) # iterator of full categorical cuts across all
    iterations
tcuts = dict() # cuts and groups along all selected features

for citer, sel in tsels.items(): # cuts across all selected features
    tcuts[citer] = dict()
    for ind, j in enumerate(sel['js']):
        tcuts[citer][j] = {
            'variable': tsels[citer]['variables'][ind],
            'type': tsels[citer]['types'][ind],
            'cuts': list(),
            'groups': dict()
        }

    # Cuts
    while ccontrow.iter < citer: # previous iteration may select no
        continuous feature
        ccontrow = next(itcont)
    while ccatrow.iter < citer: # previous iteration may select no
        categorical feature
```

```
        ccatrow = next(itcat)
    for jcur in sorted(sel['js']): # numerically sorted features selected
        cuts = tcuts[citer][jcur]['cuts'] # list of cuts along specific selected feature
        try: # iterate over full continuous cuts
            while ccontrow.iter == citer:
                if ccontrow.j > jcur: # seek no more than current feature
                    break
                else:
                    if ccontrow.j == jcur: # at current selected feature
                        cuts.append(ccontrow.bc) # continuous feature seen
                    ccontrow = next(itcont) # update DataFrame iterator
        except StopIteration:
            pass
        try: # iterate over full categorical cuts
            while ccatrow.iter == citer:
                if ccatrow.j > jcur: # seek no more than current feature
                    break
                else:
                    if ccatrow.j == jcur: # at current selected feature
                        cuts.append(ccatrow.v) # categorical feature seen
                    ccatrow = next(itcat) # update DataFrame iterator
        except StopIteration:
            pass

    # Groups
    pcutdc = dict(zip(tsels[citer]['js'], tsels[citer]['ps'])) # cut numbers along selected features
    for j, info in tcuts[citer].items():
        pnum = pcutdc[j] # number of cuts on current selected feature
        cuts = info['cuts']
        if info['type'] == 'cont': # continuous feature
            excuts = [-np.inf] + cuts + [np.inf]
```

```
                intvs = pd.arrays.IntervalArray.from_breaks(
                    breaks=excuts,
                    copy=False, # default: False
                    closed=intvclosed, # types of Pandas interval sides
                    dtype=pd.IntervalDtype(subtype=intvsubtype) # types of Pandas interval bounds
                )
                info['groups'] = {gr: intvs[gr] for gr in range(pnum+1)}
            else: # categorical feature
                info['groups'] = {gr: set() for gr in range(pnum+1)}
                for val, gr in enumerate(cuts):
                    info['groups'][gr].add(val) # categorical value in cut/group

    return tcuts
```

Code 4.8: True decision regions (module/model/findtregs.py)

```
import numpy as np
import pandas as pd

from module.operation.xutil import max_dictval, itvpos


# Calculate new true decision regions and predictions (truly correct)
def findtregs(tsels, tcuts, df, pdtype=np.int16):
    '''
        Usage: calculate new true decision regions and predictions (per file)
        Required arguments:
            tsels: dictionary of selected variables and given number of cuts
            tcuts: dictionary of cuts and groups along all selected features
```

```
            df: training dataset including target variable (DataFrame, not iterator)
        Optional arguments:
            pdtype: NumPy data type of cut number (default: np.int16)
        Outputs:
            ttregs: dictionary of new true decision regions and their predicted classes
    '''

    ttregs = dict() # new true regions with predicted classes (truly correct)
    classes = df['class'].unique() # all possible classes

    for citer in tsels.keys():
        regs = pd.Series([0]*len(df))
        js = tsels[citer]['js']
        pcutn = np.array(tsels[citer]['ps'], dtype=pdtype) # new cut numbers
        pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=pdtype) # cumulative number of new box regions
        BN = np.prod(pcutn+1) # number of new regions

        # Convert base representation of decision region to base 10
        for ind, j in enumerate(js):
            info = tcuts[citer][j]
            attr = info['variable']
            cuts = info['cuts']
            if info['type'] == 'cont': # continuous feature
                regs = regs + pncum[ind]*df[attr].apply(lambda x: itvpos(x, cuts))
            else: # categorical feature
                regs = regs + pncum[ind]*pd.Series([cuts[x] for x in df[attr]])

        # Find predicted classes in decision regions
        ttregs[citer] = {
```

```python
            b: {
                'classes': set(), # true predicted class set
                'correct': 0, # number of instances correctly predicted
                'ninst': 0, # number of training instances (total)
                'ncinst': {n: 0 for n in range(len(classes))} # number of training instances in targets
            } for b in range(BN)
        }
        for i in range(len(df)):
            ttregs[citer][regs[i]]['ninst'] += 1 # instance in region
            ttregs[citer][regs[i]]['ncinst'][df['class'][i]] += 1 # instance of specific target in region
        for b in range(BN):
            kmax, vmax = max_dictval(ttregs[citer][b]['ncinst']) # true majority voting
            ttregs[citer][b]['classes'] = kmax # all classes that have maximum number of instances
            ttregs[citer][b]['correct'] = vmax # maximum number of instances

    return ttregs
```

Code 4.9: CPLEX decision regions (module/model/findcregs.py)

```python
import numpy as np

from module.operation.typecast import strtoset
from module.operation.calregs import calregs


# Calculate new cplex decision regions and predictions (partially correct)
def findcregs(tsels, itpred, pcuto, idtype=np.int16, pdtype=np.int16):
    '''
        Usage: calculate new cplex decision regions and predictions (per file)
```

```python
        Required arguments:
            tsels: dictionary of selected variables and given number of cuts
            itpred: individual result of cplex prediction (DataFrame iterator)
            pcuto: old cut numbers
        Optional arguments:
            pdtype: NumPy data type of cut number (default: np.int16)
            idtype: NumPy data type of index (default: np.int16)
        Outputs:
            tcregs: dictionary of new cplex decision regions and their predicted classes
    '''

    cprow = next(itpred) # iterator of instance predictions across all iterations
    tcregs = dict() # new cplex regions with predicted classes (partially correct)
    classes = set() # set all possible classes (collected from training dataset)

    citer = -1 # current iteration

    while True: # reported by cplex as occupied region
        try:
            if cprow.iter != citer: # new iteration
                citer = cprow.iter
                if citer in tsels.keys(): # current iteration actually selects at least one feature
                    keep = True # keep doing in this while loop
                    pcutn = np.array(tsels[citer]['ps'], dtype=pdtype)
                    sidx = np.array(tsels[citer]['js'], dtype=idtype) - 1 # index starts at 0
                    BN = np.prod(pcutn+1) # number of new regions
                    bns = calregs(pcuto, sidx) # new correspoding regions
                    tcregs[citer] = {
```

```
                    b: {
                        'lclasses': list(), # list of cplex predicted class set
                        'nlcinst': list() # list of instance number in corresponding cplex class set
                    } for b in range(BN)
                }
            else: # current iteration selects no feature
                keep = False # update iterator and go to the next while loop
        if keep and cprow.iter == citer: # every record in iteration that selects feature
            creg = tcregs[citer][bns[cprow.region]] # new cplex region
            pset = strtoset(cprow.predict) # current set of classes predicted by cplex
            classes = classes.union(pset) # add to set of all possible classes
            try: # current set of predicted classes already exists
                creg['nlcinst'][creg['lclasses'].index(pset)] += 1
            except ValueError: # new set of predicted classes
                creg['lclasses'].append(pset)
                creg['nlcinst'].append(1)
        cprow = next(itpred) # update DataFrame iterator
    except StopIteration:
        break

for cregs in tcregs.values(): # reported by cplex as unoccupied region
    for creg in cregs.values():
        if not creg['lclasses']:
            creg['lclasses'] = [classes] # predict only one of the entire set
            nlcinst = [0] # no instance reported by cplex in the rest of new regions

return tcregs
```

Code 4.10: Classification correctness (module/model/findcorr.py)

```
# Find both true and recalculated cplex correctness
def findcorr(ttregs, tcregs):
    '''
        Usage: find both true and recalculated cplex correctness (per file)
        Required arguments:
            ttregs: dictionary of new true decision regions and their predicted classes
            tcregs: dictionary of new cplex decision regions and their predicted classes
        Outputs:
            tcorr: true number of correctly classified instances per region
            ccorr: recalculated cplex number of correctly classified instances per region
    '''

    tcorr = dict() # true correctness
    ccorr = dict() # cplex correctness
    for citer, tregs in ttregs.items(): # true classification
        tcorr[citer] = {
            'correct': 0,
            'detail': {b: tregs[b]['correct'] for b in tregs.keys()}
        }
        tcorr[citer]['correct'] = sum(tcorr[citer]['detail'].values())
    for citer, cregs in tcregs.items(): # cplex classification
        ccorr[citer] = {
            'correct': 0,
            'detail': {b: 0 for b in cregs.keys()}
        }
        for b in cregs.keys():
            for soc in tcregs[citer][b]['lclasses']:
                ccorr[citer]['detail'][b] = max([ttregs[citer][b]['ncinst'][c] for c in soc])
        ccorr[citer]['correct'] = sum(ccorr[citer]['detail'].values())

```

```
    return tcorr, ccorr
```

Code 4.11: Final mixed box classifier (finalbox.py)

```
import csv
import re
import pandas as pd

from module.operation.xutil import *
from module.operation.typecast import settostr, itvtostr, itvtodesc
from module.operation.calregs import calregs
from module.model.findsels import findsels
from module.model.findcuts import findcuts
from module.model.findtregs import findtregs
from module.model.findcregs import findcregs
from module.model.findcorr import findcorr


# Parameters
pcuto = [3,3,2] # original cut numbers across all given features
isexample = True # whether example is shown
issreport = True # whether reports of feature selection are written
isrreport = True # whether reports of detailed decision regions are written

# Informational prefixes/postfixes
ts = "75305" # last digits of timestamp
data = "seltrain20num3each20" # data name (no file extension)
inprefix = f"{ts}-{data}-export-" # input filename prefix
inpostfix = "-mfullaltseltol-2-t-1440" # input filename postfix

# Required inputs
datdir = "../../../Projects/Box Classifiers/alternative/input" # directory of training instances (cplex inputs)
```

```
indir = "../../../Projects/Box Classifiers/alternative/output" # main input directory (cplex results)
datfile = f"{data}.csv" # training dataset with target variable
datpredfile = f"{inprefix}predict-instance-pcont-3{inpostfix}.csv" # individual result of cplex prediction
inerrfile = f"{inprefix}error{inpostfix}.csv" # classification errors and performance metrics
inselfile = f"{inprefix}select-var-str-pcont-3{inpostfix}.csv" # selected string variables
incutcontfile = f"{inprefix}cutcont-full-pcont-3{inpostfix}.csv" # continuous cuts
incutcatfile = f"{inprefix}cutcat-full-pcont-3{inpostfix}.csv" # categorical cuts

# Optional inputs
if issreport: # reports of feature selection must be written
    metadir = "../../../Data/Encoded/metadata" # metadata directory
    metafile = "meta-indep-pppub20enc.json" # metadata (after encoding) file
    # Relabel case-insensitive NIU values for all selected categorical features
    niudc = {'SS_YN': "NIU (aged below 15)", 'PEMLR': "NIU"}
if isrreport: # reports of detailed decision regions must be written
    clabels = {0: 'NNN', 1: 'NNY', 2: 'NY_', 3: 'YNN', 4: 'Y1Y'}

# Required outputs
outdir = f"../../../Outputs/Main/Box/{data}" # main output directory
outeperffile = f"{ts}-eperf.csv" # classification performances (accuracy/error/time)
outselfile = f"{ts}-selvarfin.csv" # selected string variables, cuts and groups
outregfile = f"{ts}-predregfin.csv" # full decision regions

# Optional outputs
outcutcontfile = f"{ts}-cutcont.csv" # continuous cuts
outcutcatfile = f"{ts}-cutcat.csv" # categorical cuts
```

```
if issreport: # reports of feature selection must be written
    outsrepwdfile = f"{ts}-report-sel-dup.csv" # with duplicate entries
    outsrepndfile = f"{ts}-report-sel-nondup.csv" # with nonduplicate
        entries
if isrreport: # reports of detailed decision regions
    outrrepwdfile = f"{ts}-report-reg-dup.csv" # with duplicate entries
    outrrepndfile = f"{ts}-report-reg-nondup.csv" # with nonduplicate
        entries

# Create main output directory (if not exist)
create_dir(outdir)

# Import datasets
dfe = pd.read_csv(f"{indir}/{inerrfile}") # cplex classification errors
    and performance metrics
dfs = pd.read_csv(f"{indir}/{inselfile}") # selected string variables
dfcont = pd.read_csv(f"{indir}/{incutcontfile}") # full continuous cuts
dfcat = pd.read_csv(f"{indir}/{incutcatfile}") # full categorical cuts
df = pd.read_csv(f"{datdir}/{datfile}") # training dataset including
    target variable
dfp = pd.read_csv(f"{indir}/{datpredfile}") # individual result of cplex
    prediction

# Initialize DataFrame iterators
itsel = dfs.itertuples() # selected string variables
itcont = dfcont.itertuples() # full continuous cuts
itcat = dfcat.itertuples() # full categorical cuts
itpred = dfp.itertuples() # individual result of cplex prediction

# Main execution
tsels = findsels(itsel, pcuto) # selected variables
tcuts = findcuts(tsels, itcont, itcat) # cuts along all selected features
ttregs = findtregs(tsels, tcuts, df) # new true regions and predicted
    classes
tcregs = findcregs(tsels, itpred, pcuto) # new cplex regions and predicted
     classes
```

```python
tcorr, ccorr = findcorr(ttregs, tcregs) # true/cplex correctness

# Calculate performance results
dfen = pd.DataFrame({
    'iter': tcorr.keys(), # iteration that selects feature
    'taccuracy': [info['correct']*100/len(df) for info in tcorr.values()], # true accuracies
    'caccuracy': [info['correct']*100/len(df) for info in ccorr.values()], # recalculated cplex accuracies
    'terror': [len(df) - info['correct'] for info in tcorr.values()], # true errors
    'cerror': [len(df) - info['correct'] for info in ccorr.values()] # recalculated cplex errors
})
dfen = pd.merge(dfen, dfe, how='outer')
dfen.rename(columns = {
    'error': 'rerror', # reported cplex errors
    'accuracy': 'raccuracy' # reported cplex accuracies
}, inplace=True)
cols = dfen.columns.tolist()
new_cols = cols[0:1] + cols[5:5+len(pcuto)] + cols[1:3] + cols[-6:-5] + cols[3:5] + cols[-7:-6] + cols[-5:]
dfen = dfen[new_cols] # rearranged columns
dfen['ms'] = dfen['ms']/60000 # convert milliseconds to minutes
dfen = dfen.rename(columns={'ms':'minute'})

# Display performance results
print(f"\n{dfen}\n")

# Examples
if isexample:
    iters = [1, 2, 15]
    for citer in iters:
        try:
            print(f"Selected features (iteration {citer})\n{tsels[citer]}\n")
```

```
            print(f"Cuts (iteration {citer})\n{tcuts[citer]}\n")
            print(f"True decision regions (iteration {citer})\n{ttregs[citer]}\n")
            print(f"Cplex decision regions (iteration {citer})\n{tcregs[citer]}\n")
            print(f"True correctness (iteration {citer})\n{tcorr[citer]}\n")
            print(f"Cplex correctness (iteration {citer})\n{ccorr[citer]}\n")
        except KeyError:
            print(f"Iteration {citer} selects no features\n")

# Export non-edited information
copy(f"{indir}/{incutcontfile}", f"{outdir}/{outcutcontfile}") # continuous cuts
copy(f"{indir}/{incutcatfile}", f"{outdir}/{outcutcatfile}") # categorical cuts

# Export performance results (accuracy/error/time)
dfen.to_csv(f"{outdir}/{outeperffile}", float_format="%.2f", header=True, index=False)

# Export selected variables, cuts and groups
with open(f"{outdir}/{outselfile}", 'w', newline='') as file:
    writer = csv.DictWriter(
        file,
        fieldnames = [
            'iter', 'jfin', 'j', 'var', 'type',
            'p', 'cuts', 'groups'
        ]
    )
    writer.writeheader()
for citer, info in tsels.items():
    cuts = [[round(cut, 2) for cut in tcuts[citer][j]['cuts']] for j in info['js']]
    groups = list()
```

```
    for ind, j in enumerate(info['js']):
        if info['types'][ind] == 'cont': # continuous feature
            jgrs = dict()
            for gr, member in tcuts[citer][j]['groups'].items():
                jgrs[gr] = itvtostr(member)
            groups.append(jgrs)
        else: # categorical feature
            groups.append(tcuts[citer][j]['groups'])
    dfstmp = pd.DataFrame({
        'iter': citer,
        'jfin': range(1, len(info['js'])+1), # 1, 2, ...
        'j': info['js'], # j in cplex model
        'variable': info['variables'],
        'type': info['types'],
        'p': info['ps'],
        'cuts': cuts,
        'groups': groups
    })
    dfstmp.to_csv(f"{outdir}/{outselfile}", mode='a', header=False, index=
        False)
del dfstmp

# Export predicted classes and number of instances in all decision regions
with open(f"{outdir}/{outregfile}", 'w', newline='') as file:
    writer = csv.DictWriter(
        file,
        fieldnames = ['iter', 'reg', 'ninst', 'tpred', 'cpred',
                    'tcorr', 'ccorr', 'ncinst']
    )
    writer.writeheader()
    for citer, tregs in ttregs.items():
        for b, treg in tregs.items():
            writer.writerow({
                'iter': citer,
                'reg': b,
                'ninst': treg['ninst'], # number of instances
```

```
                'tpred': settostr(treg['classes']), # true predicted class
                'cpred': ','.join([settostr(st) for st in tcregs[citer][b]['lclasses']]), # cplex predicted class
                'tcorr': tcorr[citer]['detail'][b], # true correctness
                'ccorr': ccorr[citer]['detail'][b], # cplex correctness
                'ncinst': treg['ncinst'] # targets and number of member instances
            })



# Export final reports of feature selection (with duplicate/nonduplicate entries) (if specified)

if issreport: # reports of feature selection must be written

    # New labels of selected categorical features (catvdc)
    metadc = import_dict(jsonpath=f"{metadir}/{metafile}") # metadata after encoding
    catvars = set() # all selected categorical features (initialized)
    pattern = r'(^|[^\w])(niu)([^\w]|$)' # regex to search for niu
    pattern = re.compile(pattern, re.IGNORECASE)
    for info in tsels.values():
        for ind, attr in enumerate(info['variables']):
            if info['types'][ind] == 'cat':
                catvars.add(attr)
    catvdc = {attr: metadc[attr]['values'] for attr in catvars} # labels of selected categorical features
    for attr, valdc in catvdc.items():
        for val, desc in valdc.items():
            matches = re.search(pattern, desc.replace(',', ' '))
            if bool(matches): # case-insensitive value label containing niu
                try:
                    catvdc[attr][val] = niudc[attr] # relabel
                except KeyError: # new NIU label of current feature is missing
                    pass
```

```python

# True classification accuracies and performance metrics
efields = ['iter', 'taccuracy', 'minute', 'acctmin', 'status']

# Groups
grls = list() # list of all member groups across all features and iterations
for citer, scuts in tcuts.items():
    for j, info in scuts.items(): # cuts along all selected feature
        vartype = 'Continuous' if info['type']=='cat' else 'Categorical'
        if info['type'] == 'cont': # continuous feature (groups not displayed for convenience)
            for gr, member in info['groups'].items():
                dc = {
                    'iter': citer,
                    'j': j, 'variable': info['variable'],
                    'type': 'Continuous',
                    'label': metadc[info['variable']]['label'],
                    'group': gr,
                    'member': itvtostr(member),
                    'desc': itvtodesc(member, decimals=0, extend=False).capitalize()
                }
                grls.append(dc)
        else: # categorical feature (groups displayed)
            for gr, member in info['groups'].items():
                for elem in member: # all elements in group member
                    desc = catvdc[info['variable']][str(elem)]
                    dc = {
                        'iter': citer,
                        'j': j, 'variable': info['variable'],
                        'type': 'Categorical',
                        'label': metadc[info['variable']]['label'],
                        'group': gr,
                        'member': elem,
```

```
                            'desc': desc
                        }
                        grls.append(dc)
    dfg = pd.DataFrame(grls) # group dataframe

    # Report dataframe of feature selection with duplicate entries (dfrp)
    dfsrp = pd.merge(dfen[efields], dfg) # merge two dataframes: error/metric and group

    # Report dataframe of feature selection with nonduplicate entries (dfn)
    dfsrpn = nondup(
        dfsrp,
        ndcols=[
            ['iter', 'taccuracy', 'minute', 'acctmin', 'status'],
            ['j', 'variable', 'type', 'label'],
            ['group']
        ],
        intcols=['iter', 'status', 'j', 'group'] # integer columns
    )

    # Export final reports of feature selection
    dfsrp.to_csv( # with duplicate entries
        f"{outdir}/{outsrepwdfile}",
        float_format="%.2f",
        header=True, index=False
    )
    dfsrpn.to_csv( # with nonduplicate entries
        f"{outdir}/{outsrepndfile}",
        sep=',', na_rep='',
        float_format="%.2f",
        header=True, index=False
    )

print(f"{dfsrp.head()}\n") # feature selection (with duplicate entries)
print(f"{dfsrpn.head()}\n") # feature selection (with nonduplicate entries)
```

```python


# Export final reports of detailed decision regions (with duplicate/nonduplicate entries) (if specified)

if isrreport: # reports of detailed decision regions must be written

    # Export final reports of detailed regions (with duplicate entries)
    with open(f"{outdir}/{outrrepwdfile}", 'w', newline='') as file:
        writer = csv.DictWriter(
            file,
            fieldnames = [
                'iter',
                'ordvars', 'strvars',
                'reg', 'ordreg', 'crossreg',
                'tpreds', 'strtpreds',
                'ninst'
            ])
        writer.writeheader()
        for citer, tregs in ttregs.items():
            strvars = ', '.join(tsels[citer]['variables'])
            ps = tsels[citer]['ps']
            qs = [0]*len(ps) # base representation of numerical decision region
            js = tsels[citer]['js']
            for b, treg in tregs.items():
                grls = list() # list of group members
                for ind in range(len(ps)):
                    member = tcuts[citer][js[ind]]['groups'][qs[ind]]
                    if isinstance(member, pd._libs.interval.Interval): # Pandas interval
                        grls.append(itvtostr(member))
                    elif isinstance(member, set): # set
                        grls.append(settostr(member))
                    else:
```

```
                    raise TypeError("Cut intervals can be either Pandas intervals or sets")
            writer.writerow({
                'iter': citer,
                'ordvars': f"({','.join([str(j) for j in js])})", # ordered pair of selected features
                'strvars': strvars, # string of selected features
                'reg': b,
                'ordreg': f"({','.join([str(q) for q in qs])})", # ordered pair of numerical region
                'crossreg': ' x '.join(grls), # cross product of features in string format
                'tpreds': ','.join([str(v) for v in treg['classes']]), # true predicted classes
                'strtpreds': ', '.join([clabels[v] for v in treg['classes']]), # true predicted classes
                'ninst': treg['ninst'] # number of training instances in region
            })
            for ind in range(len(ps)): # increment base representation of region for next for loop
                qs[ind] += 1 # increment by 1
                if qs[ind] > ps[ind]: qs[ind] = 0 # new leading one
                else: break # same leading one

# Export final reports of detailed regions (with nonduplicate entries)
dfrrp = pd.read_csv(f"{outdir}/{outrrepwdfile}")
dfrrpn = nondup(dfrrp, ndcols=[['iter', 'ordvars', 'strvars']], intcols=['iter'])
dfrrpn.to_csv( # with nonduplicate entries
    f"{outdir}/{outrrepndfile}",
    sep=',', na_rep='',
    header=True, index=False
)
```

```
print(f"{dfrrp.head()}\n") # detailed decision regions (with duplicate
    entries)
print(f"{dfrrpn.head()}\n") # detailed decision regions (with nonduplicate
     entries)


# Reexamination of CPLEX Results

# Additional output files
outexffile = f"{ts}-exam-full.csv" # full cplex reexamination
outexdfile = f"{ts}-exam-diff.csv" # difference in new decision regions
outexnfile = f"{ts}-exam-diffnum.csv" # number of difference

# Convert full coordinate to position in new feature space
def tonpos(citer, coord):
    ls = list()
    for j in tsels[citer]['js']:
        if tcuts[citer][j]['type'] == 'cont':
            ls.append(itvpos(coord[j-1], tcuts[citer][j]['cuts']))
        else:
            ls.append(tcuts[citer][j]['cuts'][coord[j-1]])
    return tuple(ls)

# Compute new numerical region from given position to new feature space
def tonreg(citer, pos):
    pcutn = np.array(tsels[citer]['ps'], dtype=np.int16)
    pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=np.int16)
    return np.dot(pncum, pos)

dfpn = dfp.copy() # copy of individual result of cplex prediction
dfpn = dfpn[dfpn['iter'].isin(tsels.keys())] # exclude iterations of no
    feature selection

nregdc = dict() # new numerical regions in all iterations
for citer, info in tsels.items():
    nregdc[citer] = calregs(pcuto=pcuto,sidx=np.array(info['js'])-1)
```

```python
dfpn['creg'] = dfpn.apply(lambda x: nregdc[x.iter][x.region], axis=1) # new region based on cplex result
dfpn['tpred'] = dfpn.apply(lambda x: ttregs[x.iter][x.creg]['classes'], axis=1) # true predicted class

dfc = pd.merge(df, dfpn, how='right', left_on=df.index+1, right_on='id', suffixes=('', '_pn')) # include instance
del dfc['class_pn']
cols = dfc.columns.tolist()
new_cols = cols[len(pcuto)+1:len(pcuto)+3] + cols[0:len(pcuto)+1] + cols[-4:]
dfc = dfc[new_cols]
dfc = dfc.rename(columns={'region': 'rreg', 'predict': 'rpred'})

dfc['coord'] = dfc.iloc[:,2:len(pcuto)+2].apply(lambda x: tuple(x), axis=1) # full original coordinate
dfc['tpos'] = dfc.apply(lambda x: tonpos(x.iter, x.coord), axis=1) # true position in new feature space
dfc['treg'] = dfc.apply(lambda x: tonreg(x.iter, x.tpos), axis=1) # true decision region


dfcd = dfc[dfc['creg'] != dfc['treg']] # new cplex region differs from new true region
dfcn = dfcd.groupby('iter').size().reset_index(name='dnum') # number of difference

print(f"{dfcn}\n") # display number of difference in region recalculation
print(f"{dfcd}\n") # display difference in new regions

# Export cplex reexamination results
dfc.to_csv(f"{outdir}/{outexffile}", header=True, index=False) # full cplex reexamination
dfcd.to_csv(f"{outdir}/{outexdfile}", header=True, index=False) # difference in new decision regions
```

```
dfcn.to_csv(f"{outdir}/{outexnfile}", header=True, index=False) #
    difference number
```

CHAPTER V

RESULTS ON HEALTH INSURANCE

5.1 Training Data

The box classifier proposed in Chapter 4 is illustrated on the sample of size 100 (25 per class) and three preselected features: A_AGE, PEMLR and SS_YN. The variable description and cross tabulation analysis with five bins on a continuous feature is displayed in Table 5.1. Each bin covers at least two different insurance coverage types. Although survey participants are unique, some sample records can be the same in feature and even in target due to initial preselection of features and resultant partial loss of personal information. The sampling result can be seen during Iteration 7 in Table 5.7. This chapter investigates two contributing factors out of three based solely on highest training accuracy.

Table 5.1: Cross tabulation of sample data by preselected variables and health insurance coverage types

Preselected Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
A_AGE: Age					
Universe: All persons					
(1.917, 18.6]	4	8	2	0	5
(18.6, 35.2]	10	2	1	4	8
(35.2, 51.8]	5	1	5	2	5
(51.8, 68.4]	1	4	8	6	2
(68.4, 85.0]	0	5	4	8	0
PEMLR: Major labor force recode					
Universe: All persons					
0: NIU	4	5	2	0	4
1: Employed - at work	8	3	7	9	12
2: Employed - absent	0	0	3	1	0
3: Unemployed - on layoff	1	1	0	0	0
4: Unemployed - looking	1	1	1	0	2
5: Not in labor force - retired	0	5	5	9	0
6: Not in labor force - disabled	0	2	1	0	0

Table 5.1: Cross tabulation of sample data by preselected variables and health insurance coverage types (continued)

Preselected Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
7: Not in labor force - other	6	3	1	1	2
SS_YN: Who received social security payments either for themselves or as combined payments with other family members ?					
Universe: All persons aged 15+					
0: NIU	3	5	2	0	4
1: Yes	0	9	7	10	1
2: No	17	6	11	10	15

5.2 Decision Tree

The goal is to find up to two significant determinants of health insurance coverage out of three features namely A_AGE, PEMLR and SS_YN. The first is continuous whereas the last two are categorical. Three splits are assumed in Code 4.1 on an individual feature. Since SS_YN has only three possible values, this feature can have up to two splits. In total, there should be at most $(3+1)(3+1) = 16$ decision boxes. As a result, decision trees of at least depth 3 and at most 16 leaf nodes are considered. Code 5.1 computes the trees of depths 3, 4 and 5 built by the Gini impurity within 5 seconds each as displayed in Figures 5.1, 5.2 and 5.3 respectively. They give training accuracies of 45%, 50% and 54% with 7, 11 and 15 splitting values in total and 8, 12 and 16 decision boxes. The two splits A_AGE = 70.5 and A_AGE = 75 in Figures 5.2 and 5.3 are redundant because both cannot distinguish the classes of training instances in left and right nodes by predicting the same class label 4.

Figure 5.1: Gini-based decision tree with depth 3, 7 non-leaf nodes and 8 leaf nodes giving a training accuracy of 45%

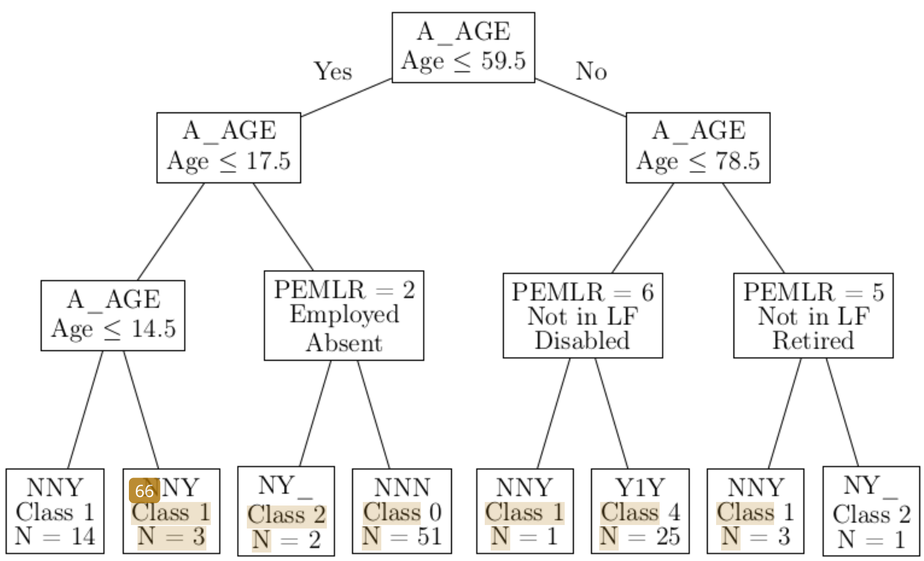


Figure 5.2: Gini-based decision tree with depth 4, 11 non-leaf nodes and 12 leaf nodes giving training accuracy of 50%

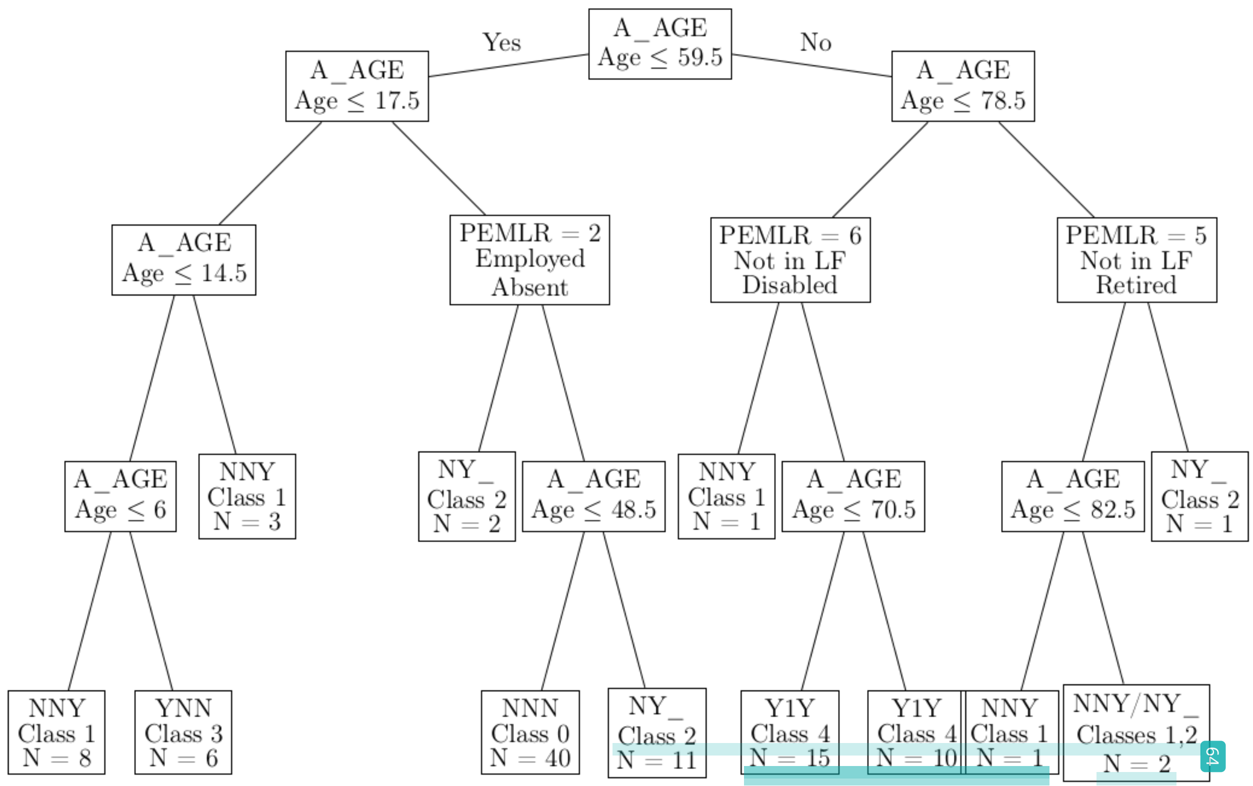
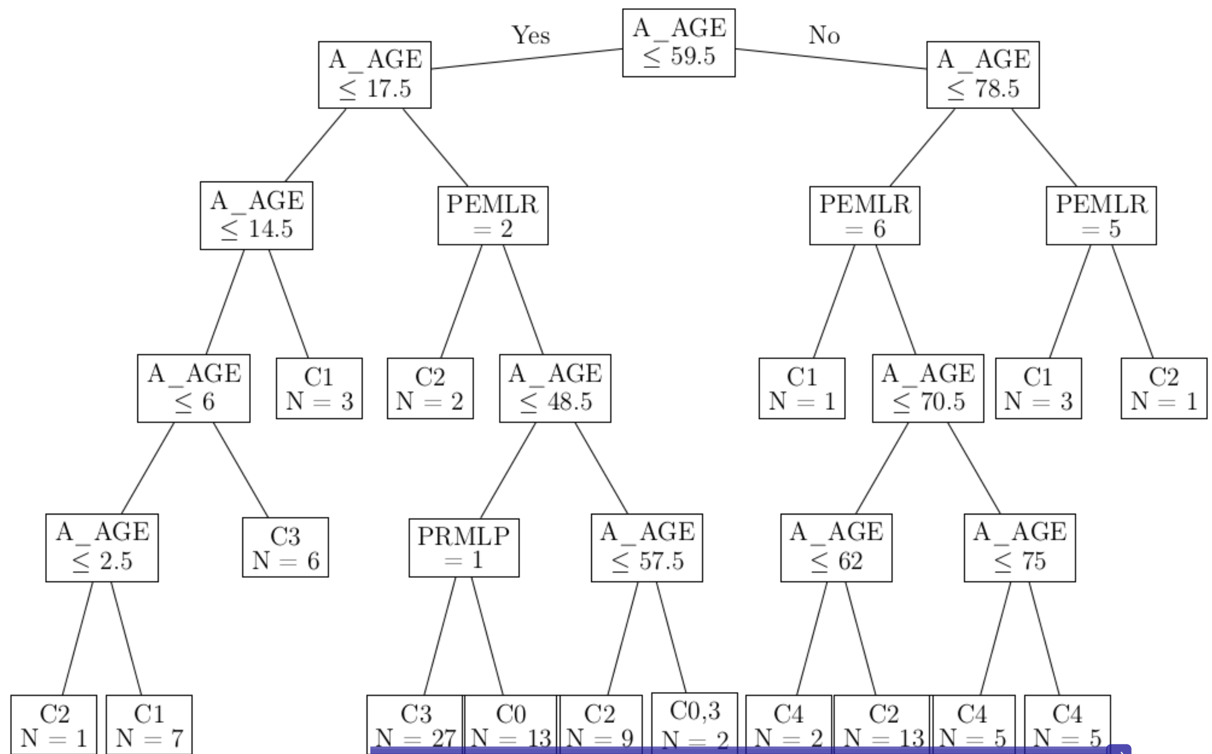


Figure 5.3: Gini-based decision tree with depth 5, 15 non-leaf nodes and 16 leaf nodes giving training accuracy of 54%



Code 5.1: Gini-based decision tree classifier

```
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import csv
import os
from sklearn.tree import DecisionTreeClassifier, export_text, plot_tree

def create_dir(dir):
    try:
        os.makedirs(dir)
    except FileExistsError:
        pass

# Given Information
data_ls = []
data_ls.append({
    'data': "../../../Samples/cplex/seltrain20num3each20.csv",
    'info': "../../../Samples/cplex/selproc20num3co3ca3cutinfo.csv",
    'configs': [
        {'max_depth': 3, 'max_leaves': 16},
        {'max_depth': 4, 'max_leaves': 16},
        {'max_depth': 5, 'max_leaves': 16}
    ],
    'outdir': "../../../Outputs/Main/Tree"
})
print(f"{data_ls}\n")

# Decision Tree
def dtree(df_data, df_info, max_depth, max_leaves, data_path='', info_path=''):

    # One-hot encoding
```

```
feat_cat = list(df_info[df_info['type'] == 'Categorical']['variable'])
for v in feat_cat:
    df_data[v] = df_data[v].astype('category')
one_hot_data = pd.get_dummies(df_data[feat_cat], drop_first=True)
X = df_data.iloc[:,0:-(len(feat_cat)+1)].join(one_hot_data)
y = df_data['class']

# Build decision tree
clf = DecisionTreeClassifier(
    max_depth=max_depth,
    max_leaf_nodes=max_leaves,
    random_state=0
)
clf.fit(X, y)

# Performance
score = clf.score(X, y)
y_pred = clf.predict(X)
err_ind = (y_pred != y.to_numpy().flatten()).astype(int)
error = np.count_nonzero(err_ind)
accuracy = (1-error/len(y_pred))*100

# Tree structure
depth = clf.tree_.max_depth
nodes = clf.tree_.node_count
leaves = clf.tree_.n_leaves
splits = nodes - leaves

# Decision tree summary
summary = {
    'error': error, 'accuracy': accuracy, 'score': score,
    'depth': depth,
    'nodes': nodes, 'leaves': leaves, 'splits': splits
}

# Decision rules
```

```python
    rules = export_text(clf, feature_names=list(X.columns))

    # Predicted values
    df_pred = pd.DataFrame({
        'y_true': df_data['class'],
        'y_pred': y_pred,
        'e': err_ind
    })

    # Display results
    if data_path != '':
        print(f"Data: {data_path}")
    if info_path != '':
        print(f"Info: {info_path}")
    print(f"Maximum depth: {max_depth}")
    print(f"Maximum number of leaves: {max_leaves}\n")
    print(f"Categorical features: {feat_cat}")
    print(f"X: {X.columns.values}\n")
    print(f"Summary:")
    print(f"\tDepth = {depth} | Leaves = {leaves}")
    print(f"\tError = {error} | Accuracy = {accuracy} | Score = {score}")
    print(f"\tNodes = {nodes} | Splits = {splits}\n")
    print(f"Decision rules:\n{rules}\n")

    # Return statement
    return clf, summary, rules, df_pred

# Implementation
for dc in data_ls:

    # Export information
    datname = os.path.splitext(os.path.basename(dc['data']))[0] # without file extension
    outdatdir = f"{dc['outdir']}/{datname}"
    outprefix = datname
    outsumfile = f"{outdatdir}/{outprefix}-summary.csv"
```

```
outruledir = f"{outdatdir}/rules"
outpreddir = f"{outdatdir}/prediction"
outfigdir = f"{outdatdir}/figures"

# Import
df_data = pd.read_csv(dc['data'])
df_info = pd.read_csv(dc['info'])

# Exported figure formats
fig_formats = ['svg', 'pgf', 'pdf']

# Create directories
create_dir(f"{outdatdir}/rules")
create_dir(f"{outdatdir}/prediction")
for format in fig_formats:
    create_dir(f"{outdatdir}/figures/{format}")

# Export summary file in CSV format
with open(outsumfile, 'w') as sumfile:

    sumheader = [
        'mdepth', 'mleaves', 'depth', 'leaves',
        'error', 'accuracy', 'score',
        'nodes', 'splits'
    ]
    writer = csv.DictWriter(sumfile, fieldnames=sumheader)
    writer.writeheader()

    for config in dc['configs']:

        # Tree configuration
        mdepth = config['max_depth'] # depth
        mleaves = config['max_leaves'] # number of leaves

        # Postfix of exported files with specific depth and number of
            leaves
```

```python
        outpostfix = f"mdepth-{mdepth}-mleaves-{mleaves}"

        # Decision tree
        clf, summary, rules, df_pred = dtree(
            df_data, df_info, mdepth, mleaves,
            data_path=dc['data'], info_path=dc['info']
        )

        # Export summary result to CSV file
        summary['mdepth'] = mdepth
        summary['mleaves'] = mleaves
        writer.writerow(summary)

        # Decision rules
        with open(f"{outruledir}/{outprefix}-rule-{outpostfix}.txt", 'w') as rulefile:
            rulefile.write(rules)

        # Prediction
        outpredfile = f"{outpreddir}/{outprefix}-pred-{outpostfix}.csv"
        df_pred.index = df_pred.index + 1
        df_pred.to_csv(outpredfile, index_label='id')

        # Tree plots
        plot_tree(clf)
        #plot_tree(clf, label='none', impurity=False)
        for format in fig_formats:
            outfigfile = f"{outfigdir}/{format}/{outprefix}-fig-{outpostfix}.{format}"
            plt.savefig(outfigfile, bbox_inches='tight')
        #plt.show()

        # Newline
        print()
```

5.3 Proposed Model

A record of an MIP solution returned by a CPLEX solver is counted as an iteration. The proposed box classifier is given within 15 iterations as reported by the solver, or 13 iterations by careful reexamination, before all CPLEX node files fully occupy the reserved disk space of 200 GB where the optimal solution status is inconclusive. As shown in Tables 5.2 and 5.3, the box classifier gives six splitting values in total, three per each contributing factor, whereas all three decision trees at least seven. It achieves a high training accuracy of 51%, compared to the trees of 12 and 16 boxes at 50% and 54%. Although the first requires a significantly longer building time of at least 78.88 minutes (iteration 13) or up to 209.93 minutes (last iteration 15), the latter two output superfluous 11 and 15 total splits. Interestingly, the box classifier and all three decision trees consider A_AGE and PEMLR significant features, and they have consistent, though nonidentical, categorical splitting values on PEMLR. Based on the box classifier, PEMLR = 3, 4, 5 and 7 share similar characteristics, and they are grouped together as a new single unit or splitting value. Another group of PEMLR = 0 and 6 is also generated. Nonetheless, all decision trees lack the capability to bundle similar categorical values.

The training accuracy, the execution time and the minimum storage size of a box classifier per iteration are reported in Table 5.4. Feature selection occurs as of iteration 2. The training accuracy directly reported by a CPLEX solver as the negative of the objective value differs from the true accuracy produced and recomputed by the proposed box classifier based solely on the splitting values during the first 13 iterations. Decision regions predicted by a CPLEX solver is inconsistent with those recomputed until iteration 10. The acceptable box classifier of training accuracy 51% is given since iteration 13 within 78.88 minutes, taking up at least 5.92 GB of disk space but no more than 7 GB, and with a relative MIP gap of 6.35 defined by the relative difference between the best integer objective and the objective of the best CPLEX tree node remaining. The CPLEX engine log can be examined in an appendix.

Groups of values on selected features and their resultant box regions including predicted class labels are shown in Tables 5.5 and 5.6 respectively. Some bins as a result of feature splits may be empty, and their corresponding decision boxes are therefore nonexistent. The dimension of new continuous features in Code 4.1 is one, but iterations 2 to 9 select only categorical features. As a result, splits on the continuous feature A_AGE is redundant, and the number of decision boxes is overly reported by a CPLEX solver. After recalculating numerical decision regions and merging boxes, the difference between CPLEX and true decision regions occurs as illustrated on a per-instance basis in Table 5.7. This is possibly due to the insufficiently small CPLEX feasibility tolerance of 10^{-6} by default. At least 41 training instances suffer from this inconsistency, and all especially in iteration 7. No difference can be detected as of iteration 10.

Table 5.2: Comparison between multiple decision tree of depths 3 to 5 and proposed classifier in iterations 13 to 15 based on number of splitting values, number of decision boxes, training accuracy and execution time

Classification Model		Num of Splitting Values				Num of Boxes	Training Accuracy (%)	Execution Time (min)
Model	Specification	A_AGE	PEMLR	SS_YN	Total			
Decision tree	Depth of 3	4	3	0	7	8	45	0.08
	Depth of 4	8	3	0	11	12	50	
	Depth of 5	12	3	0	15	16	54	
Proposed classifier	Iteration 13	3	3	0	6	16	51	78.88
	Iteration 14	3	3	0	6	16	51	82.02
	Iteration 15	3	3	0	6	16	51	209.93

Table 5.3: Splitting values on features of multiple decision tree of depths 3 to 5 and proposed classifier in iterations 13 to 15

Classification Model		Splitting Values			Training Accuracy (%)
Model	Specification	A_AGE	PEMLR	SS_YN	
Decision tree	Depth of 3	14.5, 17.5, 59.5, 78.5	2, 5, 6	–	45
	Depth of 4	6, 14.5, 17.5, 48.5, 59.5, 70.5, 78.5, 82.5	2, 5, 6	–	50
	Depth of 5	2.5, 6, 14.5, 17.5, 48.5, 57.5, 59.5, 62, 70.5, 75, 78.5	2, 5, 6	–	54
Proposed classifier	Iteration 13	24.99, 55.99, 64.99	{2}, {1}, {3, 4, 5, 7}, {0, 6}	–	51
	Iterations 14 to 15	24.01, 55.99, 64.99	{2}, {1}, {3, 4, 5, 7}, {0, 6}	–	51

Table 5.4: Training accuracy, execution time, minimum storage usage, relative MIP gap and number of inconsistent data across all iterations

Iteration	Accuracy (%)			Execution Time (min)		Min Storage (GB)			Rel Gap	Inconsistent
	True	CPLEX	Reported	Each	Accum	Tree	Nodes	Comp		
1			20	0	0				279	
2	38	35	28	0.03	0.03				27.57	41
3	38	35	31	0.01	0.04				22.14	41
4	38	35	36	0.01	0.06				17.25	41
5	38	35	38	0.03	0.09				15.5	41
6	40	36	39	13.3	13.39	0.99	0	0	8.67	41
7	40	30	40	5.27	18.66	1.24	0	0	8.42	100
8	43	40	43	4.64	23.3	2.74	0.49	0.45	7.75	41
9	44	42	44	7.67	30.97	3.68	1.3	1.18	7.54	41
10	47	47	46	37.23	68.2	3.35	1.34	1.19	7.01	
11	48	48	48	1.18	69.38	3.46	1.5	1.32	6.67	
12	50	50	49	7.17	76.55	4.11	1.64	1.45	6.51	
13	51	51	50	2.33	78.88	8.13	5.92	5.17	6.35	
14	51	51	51	3.14	82.02	9.06	7	6.13	6.2	
15	51	51	51	127.91	209.93	192.68	190.58	167.06	6.08	

Table 5.5: Selected variables and groups of values across all iterations

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
2	2	PEMLR	Categorical	0	1	Employed - at work
					3	Unemployed - on layoff
					7	Not in labor force - other
				2	5	Not in labor force - retired
				3	0	NIU
					2	Employed - absent
					4	Unemployed - looking
					6	Not in labor force - disabled
	3	SS_YN	Categorical	0	2	No
				1	1	Yes
				2	0	NIU (aged below 15)
3	2	PEMLR	Categorical	0	1	Employed - at work
					3	Unemployed - on layoff
					7	Not in labor force - other
				2	5	Not in labor force - retired
				3	0	NIU

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
					2	Employed - absent
					4	Unemployed - looking
					6	Not in labor force - disabled
	3	SS_YN	Categorical	0	2	No
				1	1	Yes
				2	0	NIU (aged below 15)
4	2	PEMLR	Categorical	0	1	Employed - at work
					3	Unemployed - on layoff
					7	Not in labor force - other
				2	5	Not in labor force - retired
				3	0	NIU
					2	Employed - absent
					4	Unemployed - looking
					6	Not in labor force - disabled
	3	SS_YN	Categorical	0	2	No
				1	1	Yes

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
				2	0	NIU (aged below 15)
5	2	PEMLR	Categorical	0	1	Employed - at work
					3	Unemployed - on layoff
					7	Not in labor force - other
				2	5	Not in labor force - retired
				3	0	NIU
					2	Employed - absent
					4	Unemployed - looking
					6	Not in labor force - disabled
	3	SS_YN	Categorical	0	2	No
				1	1	Yes
				2	0	NIU (aged below 15)
6	2	PEMLR	Categorical	0	1	Employed - at work
					3	Unemployed - on layoff
					7	Not in labor force - other
				1	2	Employed - absent

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
				2	5	Not in labor force - retired
				3	0	NIU
					4	Unemployed - looking
					6	Not in labor force - disabled
	3	SS_YN	Categorical	0	2	No
				1	1	Yes
				2	0	NIU (aged below 15)
7	2	PEMLR	Categorical	0	1	Employed - at work
					2	Employed - absent
					4	Unemployed - looking
				2	0	NIU
					3	Unemployed - on layoff
					6	Not in labor force - disabled
					7	Not in labor force - other
				3	5	Not in labor force - retired
	3	SS_YN	Categorical	1	0	NIU (aged below 15)

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
					2	No
				2	1	Yes
8	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
					6	Not in labor force - disabled
				2	0	NIU
					3	Unemployed - on layoff
					4	Unemployed - looking
					7	Not in labor force - other
				3	5	Not in labor force - retired
	3	SS_YN	Categorical	0	2	No
				2	0	NIU (aged below 15)
					1	Yes
9	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	0	NIU

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
					3	Unemployed - on layoff
					4	Unemployed - looking
					6	Not in labor force - disabled
					7	Not in labor force - other
				3	5	Not in labor force - retired
	3	SS_YN	Categorical	0	2	No
				2	0	NIU (aged below 15)
					1	Yes
10	1	A_AGE	Continuous	0	$(-\infty, 24.01)$	Below 24
				1	$(24.01, 40.99)$	Between 25 and 40
				2	$(40.99, 65.99)$	Between 41 and 65
				3	$(65.99, \infty)$	Above 66
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
					7	Not in labor force - other
				2	4	Unemployed - looking

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
					5	Not in labor force - retired
				3	0	NIU
					3	Unemployed - on layoff
					6	Not in labor force - disabled
11	1	A_AGE	Continuous	0	$(-\infty, 24.01)$	Below 24
				1	$(24.01, 40.99)$	Between 25 and 40
				2	$(40.99, 64.99)$	Between 41 and 64
				3	$(64.99, \infty)$	Above 65
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
					7	Not in labor force - other
				2	4	Unemployed - looking
					5	Not in labor force - retired
				3	0	NIU
					3	Unemployed - on layoff
					6	Not in labor force - disabled

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
12	1	A_AGE	Continuous	0	$(-\infty, 24.99)$	Below 24
				1	$(24.99, 40.01)$	Between 25 and 40
				2	$(40.00, 64.01)$	Between 41 and 64
				3	$(64.01, \infty)$	Above 65
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	4	Unemployed - looking
					5	Not in labor force - retired
					7	Not in labor force - other
				3	0	NIU
					3	Unemployed - on layoff
					6	Not in labor force - disabled
13	1	A_AGE	Continuous	0	$(-\infty, 24.99)$	Below 24
				1	$(24.99, 55.99)$	Between 25 and 55
				2	$(55.99, 64.99)$	Between 56 and 64
				3	$(64.99, \infty)$	Above 65

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	3	Unemployed - on layoff
					4	Unemployed - looking
					5	Not in labor force - retired
					7	Not in labor force - other
				3	0	NIU
					6	Not in labor force - disabled
14	1	A_AGE	Continuous	0	$(-\infty, 24.01)$	Below 24
				1	$(24.01, 55.99)$	Between 25 and 55
				2	$(55.99, 64.99)$	Between 56 and 64
				3	$(64.99, \infty)$	Above 65
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	3	Unemployed - on layoff
					4	Unemployed - looking

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
					5	Not in labor force - retired
					7	Not in labor force - other
				3	0	NIU
					6	Not in labor force - disabled
15	1	A_AGE	Continuous	0	$(-\infty, 24.01)$	Below 24
				1	$(24.01, 55.99)$	Between 25 and 55
				2	$(55.99, 64.99)$	Between 56 and 64
				3	$(64.99, \infty)$	Above 65
	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	3	Unemployed - on layoff
					4	Unemployed - looking
					5	Not in labor force - retired
					7	Not in labor force - other
				3	0	NIU
					6	Not in labor force - disabled

Table 5.6: Decision regions and predicted class labels across all iterations

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
2	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,3,7\} \times \{2\}$	0	NNN	48
			1	(1,0)	$\emptyset \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			2	(2,0)	$\{5\} \times \{2\}$	2	NY_	3
			3	(3,0)	$\{0,2,4,6\} \times \{2\}$	2	NY_	8
			4	(0,1)	$\{1,3,7\} \times \{1\}$	2,4	NY_, Y1Y	6
			5	(1,1)	$\emptyset \times \{1\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{5\} \times \{1\}$	4	Y1Y	16
			7	(3,1)	$\{0,2,4,6\} \times \{1\}$	1	NNY	5
			8	(0,2)	$\{1,3,7\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			9	(1,2)	$\emptyset \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{5\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			11	(3,2)	$\{0,2,4,6\} \times \{0\}$	1	NNY	14
3	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,3,7\} \times \{2\}$	0	NNN	48
			1	(1,0)	$\emptyset \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			2	(2,0)	$\{5\} \times \{2\}$	2	NY_	3
			3	(3,0)	$\{0,2,4,6\} \times \{2\}$	2	NY_	8

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
			4	(0,1)	$\{1,3,7\} \times \{1\}$	2,4	NY_, Y1Y	6
			5	(1,1)	$\emptyset \times \{1\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{5\} \times \{1\}$	4	Y1Y	16
			7	(3,1)	$\{0,2,4,6\} \times \{1\}$	1	NNY	5
			8	(0,2)	$\{1,3,7\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			9	(1,2)	$\emptyset \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{5\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			11	(3,2)	$\{0,2,4,6\} \times \{0\}$	1	NNY	14
4	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,3,7\} \times \{2\}$	0	NNN	48
			1	(1,0)	$\emptyset \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			2	(2,0)	$\{5\} \times \{2\}$	2	NY_	3
			3	(3,0)	$\{0,2,4,6\} \times \{2\}$	2	NY_	8
			4	(0,1)	$\{1,3,7\} \times \{1\}$	2,4	NY_, Y1Y	6
			5	(1,1)	$\emptyset \times \{1\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{5\} \times \{1\}$	4	Y1Y	16
			7	(3,1)	$\{0,2,4,6\} \times \{1\}$	1	NNY	5

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
			8	(0,2)	$\{1,3,7\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			9	(1,2)	$\emptyset \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{5\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			11	(3,2)	$\{0,2,4,6\} \times \{0\}$	1	NNY	14
5	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,3,7\} \times \{2\}$	0	NNN	48
			1	(1,0)	$\emptyset \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			2	(2,0)	$\{5\} \times \{2\}$	2	NY_	3
			3	(3,0)	$\{0,2,4,6\} \times \{2\}$	2	NY_	8
			4	(0,1)	$\{1,3,7\} \times \{1\}$	2,4	NY_, Y1Y	6
			5	(1,1)	$\emptyset \times \{1\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{5\} \times \{1\}$	4	Y1Y	16
			7	(3,1)	$\{0,2,4,6\} \times \{1\}$	1	NNY	5
			8	(0,2)	$\{1,3,7\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			9	(1,2)	$\emptyset \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{5\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			11	(3,2)	$\{0,2,4,6\} \times \{0\}$	1	NNY	14

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
6	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,3,7\} \times \{2\}$	0	NNN	48
			1	(1,0)	$\{2\} \times \{2\}$	2	NY_	3
			2	(2,0)	$\{5\} \times \{2\}$	2	NY_	3
			3	(3,0)	$\{0,4,6\} \times \{2\}$	0,3	NNN, YNN	5
			4	(0,1)	$\{1,3,7\} \times \{1\}$	2,4	NY_, Y1Y	6
			5	(1,1)	$\{2\} \times \{1\}$	2	NY_	1
			6	(2,1)	$\{5\} \times \{1\}$	4	Y1Y	16
			7	(3,1)	$\{0,4,6\} \times \{1\}$	1	NNY	4
			8	(0,2)	$\{1,3,7\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			9	(1,2)	$\{2\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{5\} \times \{0\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			11	(3,2)	$\{0,4,6\} \times \{0\}$	1	NNY	14
7	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{1,2,4\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$\emptyset \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			2	(2,0)	$\{0,3,6,7\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			3	(3,0)	$\{5\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
			4	(0,1)	$\{1,2,4\} \times \{0,2\}$	3	YNN	42
			5	(1,1)	$\emptyset \times \{0,2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{0,3,6,7\} \times \{0,2\}$	0	NNN	28
			7	(3,1)	$\{5\} \times \{0,2\}$	2	NY_	3
			8	(0,2)	$\{1,2,4\} \times \{1\}$	2	NY_	6
			9	(1,2)	$\emptyset \times \{1\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			10	(2,2)	$\{0,3,6,7\} \times \{1\}$	1	NNY	5
			11	(3,2)	$\{5\} \times \{1\}$	4	Y1Y	16
8	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{2\} \times \{2\}$	2	NY_	3
			1	(1,0)	$\{1,6\} \times \{2\}$	3	YNN	35
			2	(2,0)	$\{0,3,4,7\} \times \{2\}$	0	NNN	18
			3	(3,0)	$\{5\} \times \{2\}$	2	NY_	3
			4	(0,1)	$\{2\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			5	(1,1)	$\{1,6\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{0,3,4,7\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			7	(3,1)	$\{5\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
			8	(0,2)	$\{2\} \times \{0,1\}$	2	NY_	1
			9	(1,2)	$\{1,6\} \times \{0,1\}$	2	NY_	7
			10	(2,2)	$\{0,3,4,7\} \times \{0,1\}$	1	NNY	17
			11	(3,2)	$\{5\} \times \{0,1\}$	4	Y1Y	16
9	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{2\} \times \{2\}$	2	NY_	3
			1	(1,0)	$\{1\} \times \{2\}$	3	YNN	35
			2	(2,0)	$\{0,3,4,6,7\} \times \{2\}$	0	NNN	18
			3	(3,0)	$\{5\} \times \{2\}$	2	NY_	3
			4	(0,1)	$\{2\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			5	(1,1)	$\{1\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			6	(2,1)	$\{0,3,4,6,7\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			7	(3,1)	$\{5\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			8	(0,2)	$\{2\} \times \{0,1\}$	2	NY_	1
			9	(1,2)	$\{1\} \times \{0,1\}$	2	NY_	4
			10	(2,2)	$\{0,3,4,6,7\} \times \{0,1\}$	1	NNY	20
			11	(3,2)	$\{5\} \times \{0,1\}$	4	Y1Y	16

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
10	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.01) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.01, 40.99) \times \{2\}$	2	NY_	2
			2	(2,0)	$(40.99, 65.99) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(65.99, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.01) \times \{1, 7\}$	0	NNN	11
			5	(1,1)	$(24.01, 40.99) \times \{1, 7\}$	3	YNN	17
			6	(2,1)	$(40.99, 65.99) \times \{1, 7\}$	3	YNN	20
			7	(3,1)	$(65.99, \infty) \times \{1, 7\}$	2,4	NY_, Y1Y	4
			8	(0,2)	$(-\infty, 24.01) \times \{4, 5\}$	1,3	NNY, YNN	2
			9	(1,2)	$(24.01, 40.99) \times \{4, 5\}$	0,3	NNN, YNN	2
			10	(2,2)	$(40.99, 65.99) \times \{4, 5\}$	2	NY_	4
			11	(3,2)	$(65.99, \infty) \times \{4, 5\}$	4	Y1Y	16
			12	(0,3)	$(-\infty, 24.01) \times \{0, 3, 6\}$	1	NNY	15
			13	(1,3)	$(24.01, 40.99) \times \{0, 3, 6\}$	0	NNN	1
			14	(2,3)	$(40.99, 65.99) \times \{0, 3, 6\}$	1	NNY	3
			15	(3,3)	$(65.99, \infty) \times \{0, 3, 6\}$	1	NNY	1

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
11	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.01) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.01, 40.99) \times \{2\}$	2	NY_	2
			2	(2,0)	$(40.99, 64.99) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(64.99, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.01) \times \{1, 7\}$	0	NNN	11
			5	(1,1)	$(24.01, 40.99) \times \{1, 7\}$	3	YNN	17
			6	(2,1)	$(40.99, 64.99) \times \{1, 7\}$	3	YNN	18
			7	(3,1)	$(64.99, \infty) \times \{1, 7\}$	2,4	NY_, Y1Y	6
			8	(0,2)	$(-\infty, 24.01) \times \{4, 5\}$	1,3	NNY, YNN	2
			9	(1,2)	$(24.01, 40.99) \times \{4, 5\}$	0,3	NNN, YNN	2
			10	(2,2)	$(40.99, 64.99) \times \{4, 5\}$	2	NY_	4
			11	(3,2)	$(64.99, \infty) \times \{4, 5\}$	4	Y1Y	16
			12	(0,3)	$(-\infty, 24.01) \times \{0, 3, 6\}$	1	NNY	15
			13	(1,3)	$(24.01, 40.99) \times \{0, 3, 6\}$	0	NNN	1
			14	(2,3)	$(40.99, 64.99) \times \{0, 3, 6\}$	1	NNY	3
			15	(3,3)	$(64.99, \infty) \times \{0, 3, 6\}$	1	NNY	1

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
12	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.99) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.99, 40.01) \times \{2\}$	2	NY_	2
			2	(2,0)	$(40.00, 64.01) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(64.01, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.99) \times \{1\}$	0	NNN	7
			5	(1,1)	$(24.99, 40.01) \times \{1\}$	3	YNN	14
			6	(2,1)	$(40.00, 64.01) \times \{1\}$	3	YNN	13
			7	(3,1)	$(64.01, \infty) \times \{1\}$	2	NY_	5
			8	(0,2)	$(-\infty, 24.99) \times \{4, 5, 7\}$	1	NNY	6
			9	(1,2)	$(24.99, 40.01) \times \{4, 5, 7\}$	0	NNN	5
			10	(2,2)	$(40.00, 64.01) \times \{4, 5, 7\}$	2	NY_	9
			11	(3,2)	$(64.01, \infty) \times \{4, 5, 7\}$	4	Y1Y	17
			12	(0,3)	$(-\infty, 24.99) \times \{0, 3, 6\}$	1	NNY	15
			13	(1,3)	$(24.99, 40.01) \times \{0, 3, 6\}$	0	NNN	1
			14	(2,3)	$(40.00, 64.01) \times \{0, 3, 6\}$	1	NNY	3
			15	(3,3)	$(64.01, \infty) \times \{0, 3, 6\}$	1	NNY	1

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
13	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.99) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.99, 55.99) \times \{2\}$	2	NY_	2
			2	(2,0)	$(55.99, 64.99) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(64.99, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.99) \times \{1\}$	0	NNN	7
			5	(1,1)	$(24.99, 55.99) \times \{1\}$	3	YNN	23
			6	(2,1)	$(55.99, 64.99) \times \{1\}$	3	YNN	4
			7	(3,1)	$(64.99, \infty) \times \{1\}$	2	NY_	5
			8	(0,2)	$(-\infty, 24.99) \times \{3, 4, 5, 7\}$	1	NNY	6
			9	(1,2)	$(24.99, 55.99) \times \{3, 4, 5, 7\}$	0	NNN	9
			10	(2,2)	$(55.99, 64.99) \times \{3, 4, 5, 7\}$	2	NY_	7
			11	(3,2)	$(64.99, \infty) \times \{3, 4, 5, 7\}$	4	Y1Y	17
			12	(0,3)	$(-\infty, 24.99) \times \{0, 6\}$	1	NNY	15
			13	(1,3)	$(24.99, 55.99) \times \{0, 6\}$	1	NNY	1
			14	(2,3)	$(55.99, 64.99) \times \{0, 6\}$	2	NY_	1
			15	(3,3)	$(64.99, \infty) \times \{0, 6\}$	1	NNY	1

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
14	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.01) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.01, 55.99) \times \{2\}$	2	NY_	2
			2	(2,0)	$(55.99, 64.99) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(64.99, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.01) \times \{1\}$	0	NNN	7
			5	(1,1)	$(24.01, 55.99) \times \{1\}$	3	YNN	23
			6	(2,1)	$(55.99, 64.99) \times \{1\}$	3	YNN	4
			7	(3,1)	$(64.99, \infty) \times \{1\}$	2	NY_	5
			8	(0,2)	$(-\infty, 24.01) \times \{3, 4, 5, 7\}$	1	NNY	6
			9	(1,2)	$(24.01, 55.99) \times \{3, 4, 5, 7\}$	0	NNN	9
			10	(2,2)	$(55.99, 64.99) \times \{3, 4, 5, 7\}$	2	NY_	7
			11	(3,2)	$(64.99, \infty) \times \{3, 4, 5, 7\}$	4	Y1Y	17
			12	(0,3)	$(-\infty, 24.01) \times \{0, 6\}$	1	NNY	15
			13	(1,3)	$(24.01, 55.99) \times \{0, 6\}$	1	NNY	1
			14	(2,3)	$(55.99, 64.99) \times \{0, 6\}$	2	NY_	1
			15	(3,3)	$(64.99, \infty) \times \{0, 6\}$	1	NNY	1

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
15	(1,2)	A_AGE, PEMLR	0	(0,0)	$(-\infty, 24.01) \times \{2\}$	0,1,2,3,4	NNN, NNY, NY_, YNN, Y1Y	0
			1	(1,0)	$(24.01, 55.99) \times \{2\}$	2	NY_	2
			2	(2,0)	$(55.99, 64.99) \times \{2\}$	4	Y1Y	1
			3	(3,0)	$(64.99, \infty) \times \{2\}$	2	NY_	1
			4	(0,1)	$(-\infty, 24.01) \times \{1\}$	0	NNN	7
			5	(1,1)	$(24.01, 55.99) \times \{1\}$	3	YNN	23
			6	(2,1)	$(55.99, 64.99) \times \{1\}$	3	YNN	4
			7	(3,1)	$(64.99, \infty) \times \{1\}$	2	NY_	5
			8	(0,2)	$(-\infty, 24.01) \times \{3, 4, 5, 7\}$	1	NNY	6
			9	(1,2)	$(24.01, 55.99) \times \{3, 4, 5, 7\}$	0	NNN	9
			10	(2,2)	$(55.99, 64.99) \times \{3, 4, 5, 7\}$	2	NY_	7
			11	(3,2)	$(64.99, \infty) \times \{3, 4, 5, 7\}$	4	Y1Y	17
			12	(0,3)	$(-\infty, 24.01) \times \{0, 6\}$	1	NNY	15
			13	(1,3)	$(24.01, 55.99) \times \{0, 6\}$	1	NNY	1
			14	(2,3)	$(55.99, 64.99) \times \{0, 6\}$	2	NY_	1
			15	(3,3)	$(64.99, \infty) \times \{0, 6\}$	1	NNY	1

Table 5.7: Inconsistency between numerical CPLEX and true decision regions

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
2	8	4	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	10	12	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	20	10	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	21	85	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	22	74	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	23	64	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	24	73	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	26	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	27	4	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	28	10	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	29	54	6	1	1	26	1	6	(3, 1)	7	4
	30	3	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	33	17	4	1	1	26	1	6	(3, 1)	7	4
	35	77	6	1	1	26	1	6	(3, 1)	7	4
	36	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	37	80	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	40	21	7	1	1	14	2	3	(0, 1)	4	2
	44	79	1	1	2	14	2	3	(0, 1)	4	2
	47	5	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	48	76	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	51	2	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	53	67	1	1	2	14	2	3	(0, 1)	4	2
	54	67	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	56	85	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	58	70	2	1	2	26	1	6	(3, 1)	7	4
	60	56	6	1	2	26	1	6	(3, 1)	7	4
	64	63	1	1	3	14	2	3	(0, 1)	4	2
	65	14	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	74	4	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	75	12	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	78	7	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	87	73	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	90	76	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	91	77	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	93	71	1	1	4	14	2	3	(0, 1)	4	2
	94	70	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	95	78	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	96	67	7	1	4	14	2	3	(0, 1)	4	2
	97	71	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	98	66	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	99	67	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
3	8	4	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	10	12	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	20	10	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	21	85	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	22	74	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	23	64	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	24	73	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	26	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	27	4	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	28	10	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	29	54	6	1	1	26	1	6	(3, 1)	7	4
	30	3	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	33	17	4	1	1	26	1	6	(3, 1)	7	4
	35	77	6	1	1	26	1	6	(3, 1)	7	4
	36	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	37	80	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	40	21	7	1	1	14	2	3	(0, 1)	4	2
	44	79	1	1	2	14	2	3	(0, 1)	4	2
	47	5	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	48	76	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	51	2	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	53	67	1	1	2	14	2	3	(0, 1)	4	2
	54	67	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	56	85	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	58	70	2	1	2	26	1	6	(3, 1)	7	4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	60	56	6	1	2	26	1	6	(3, 1)	7	4
	64	63	1	1	3	14	2	3	(0, 1)	4	2
	65	14	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	74	4	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	75	12	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	78	7	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	87	73	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	90	76	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	91	77	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	93	71	1	1	4	14	2	3	(0, 1)	4	2
	94	70	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	95	78	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	96	67	7	1	4	14	2	3	(0, 1)	4	2
	97	71	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	98	66	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	99	67	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
4	8	4	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	10	12	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	20	10	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	21	85	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	22	74	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	23	64	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	24	73	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	26	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	27	4	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	28	10	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	29	54	6	1	1	26	1	6	(3, 1)	7	4
	30	3	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	33	17	4	1	1	26	1	6	(3, 1)	7	4
	35	77	6	1	1	26	1	6	(3, 1)	7	4
	36	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	37	80	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	40	21	7	1	1	14	2	3	(0, 1)	4	2
	44	79	1	1	2	14	2	3	(0, 1)	4	2
	47	5	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	48	76	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	51	2	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	53	67	1	1	2	14	2	3	(0, 1)	4	2
	54	67	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	56	85	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	58	70	2	1	2	26	1	6	(3, 1)	7	4
	60	56	6	1	2	26	1	6	(3, 1)	7	4
	64	63	1	1	3	14	2	3	(0, 1)	4	2
	65	14	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	74	4	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	75	12	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	78	7	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	87	73	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	90	76	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	91	77	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	93	71	1	1	4	14	2	3	(0, 1)	4	2
	94	70	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	95	78	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	96	67	7	1	4	14	2	3	(0, 1)	4	2
	97	71	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	98	66	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	99	67	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
5	8	4	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	10	12	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	20	10	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	21	85	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	22	74	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	23	64	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	24	73	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	26	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	27	4	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	28	10	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	29	54	6	1	1	26	1	6	(3, 1)	7	4
	30	3	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	33	17	4	1	1	26	1	6	(3, 1)	7	4
	35	77	6	1	1	26	1	6	(3, 1)	7	4
	36	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	37	80	5	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	40	21	7	1	1	14	2	3	(0, 1)	4	2
	44	79	1	1	2	14	2	3	(0, 1)	4	2
	47	5	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	48	76	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	51	2	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	53	67	1	1	2	14	2	3	(0, 1)	4	2
	54	67	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	56	85	5	1	2	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	58	70	2	1	2	26	1	6	(3, 1)	7	4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	60	56	6	1	2	26	1	6	(3, 1)	7	4
	64	63	1	1	3	14	2	3	(0, 1)	4	2
	65	14	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	74	4	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	75	12	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	78	7	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	87	73	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	90	76	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	91	77	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	93	71	1	1	4	14	2	3	(0, 1)	4	2
	94	70	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	95	78	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	96	67	7	1	4	14	2	3	(0, 1)	4	2
	97	71	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	98	66	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
	99	67	5	1	4	22	4	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
6	8	4	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	10	12	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	20	10	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	21	85	5	1	1	22	4	5	(2, 1)	6	2
	22	74	5	1	1	22	4	5	(2, 1)	6	2
	23	64	5	1	1	22	4	5	(2, 1)	6	2
	24	73	5	1	1	22	4	5	(2, 1)	6	2
	26	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	27	4	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	28	10	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	29	54	6	1	1	26	1	6	(3, 1)	7	4
	30	3	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	33	17	4	1	1	26	1	6	(3, 1)	7	4
	35	77	6	1	1	26	1	6	(3, 1)	7	4
	36	5	0	0	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	37	80	5	1	1	22	4	5	(2, 1)	6	2

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	40	21	7	1	1	14	2,3	3	(0, 1)	4	0, 3
	44	79	1	1	2	14	2,3	3	(0, 1)	4	0, 3
	47	5	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	48	76	5	1	2	22	4	5	(2, 1)	6	2
	51	2	0	0	2	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	53	67	1	1	2	14	2,3	3	(0, 1)	4	0, 3
	54	67	5	1	2	22	4	5	(2, 1)	6	2
	56	85	5	1	2	22	4	5	(2, 1)	6	2
	58	70	2	1	2	18	2	4	(1, 1)	5	2, 4
	60	56	6	1	2	26	1	6	(3, 1)	7	4
	64	63	1	1	3	14	2,3	3	(0, 1)	4	0, 3
	65	14	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	74	4	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	75	12	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	78	7	0	0	3	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
	87	73	5	1	4	22	4	5	(2, 1)	6	2
	90	76	5	1	4	22	4	5	(2, 1)	6	2

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	91	77	5	1	4	22	4	5	(2, 1)	6	2
	93	71	1	1	4	14	2,3	3	(0, 1)	4	0, 3
	94	70	5	1	4	22	4	5	(2, 1)	6	2
	95	78	5	1	4	22	4	5	(2, 1)	6	2
	96	67	7	1	4	14	2,3	3	(0, 1)	4	0, 3
	97	71	5	1	4	22	4	5	(2, 1)	6	2
	98	66	5	1	4	22	4	5	(2, 1)	6	2
	99	67	5	1	4	22	4	5	(2, 1)	6	2
7	1	24	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	2	58	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	3	24	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	4	40	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	5	24	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	6	26	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	7	18	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	8	4	0	0	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	9	38	3	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	10	12	0	0	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	11	46	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	12	26	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	13	35	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	14	19	7	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	15	29	4	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	16	24	0	2	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	17	35	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	18	48	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	19	41	1	2	0	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	20	10	0	0	0	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	21	85	5	1	1	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	22	74	5	1	1	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	23	64	5	1	1	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	24	73	5	1	1	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	25	15	7	2	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	26	5	0	0	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	27	4	0	0	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	28	10	0	0	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	29	54	6	1	1	34	1	8	(2, 2)	10	2
	30	3	0	0	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	31	45	3	2	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	32	28	1	2	1	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	33	17	4	1	1	26	2	6	(0, 2)	8	0
	34	57	1	2	1	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	35	77	6	1	1	34	1	8	(2, 2)	10	2
	36	5	0	0	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	37	80	5	1	1	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	38	16	1	2	1	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	39	57	7	2	1	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	40	21	7	1	1	34	1	8	(2, 2)	10	2
	41	56	4	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	42	64	5	2	2	26	2	6	(3, 1)	7	0

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	43	38	2	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	44	79	1	1	2	26	2	6	(0, 2)	8	0
	45	57	7	2	2	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	46	65	1	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	47	5	0	0	2	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	48	76	5	1	2	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	49	49	1	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	50	37	2	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	51	2	0	0	2	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	52	41	1	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	53	67	1	1	2	26	2	6	(0, 2)	8	0
	54	67	5	1	2	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	55	63	5	2	2	26	2	6	(3, 1)	7	0
	56	85	5	1	2	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	57	19	1	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	58	70	2	1	2	26	2	6	(0, 2)	8	0
	59	38	1	2	2	14	3	3	(0, 1)	4	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	60	56	6	1	2	34	1	8	(2, 2)	10	2
	61	29	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	62	26	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	63	59	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	64	63	1	1	3	26	2	6	(0, 2)	8	0
	65	14	0	0	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	66	22	4	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	67	25	7	2	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	68	18	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	69	25	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	70	46	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	71	40	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	72	29	4	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	73	33	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	74	4	0	0	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	75	12	0	0	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	76	51	7	2	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	77	29	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	78	7	0	0	3	22	0	5	(2, 1)	6	0, 1, 2, 3, 4
	79	51	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	80	41	1	2	3	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	81	78	5	2	4	26	2	6	(3, 1)	7	0
	82	60	2	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	83	27	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	84	65	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	85	22	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	86	42	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	87	73	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	88	45	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	89	26	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	90	76	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	91	77	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	92	27	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
	93	71	1	1	4	26	2	6	(0, 2)	8	0

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	94	70	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	95	78	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	96	67	7	1	4	34	1	8	(2, 2)	10	2
	97	71	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	98	66	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	99	67	5	1	4	38	4	9	(3, 2)	11	0, 1, 2, 3, 4
	100	61	1	2	4	14	3	3	(0, 1)	4	0, 1, 2, 3, 4
8	8	4	0	0	0	34	1	8	(2, 2)	10	2
	10	12	0	0	0	34	1	8	(2, 2)	10	2
	20	10	0	0	0	34	1	8	(2, 2)	10	2
	21	85	5	1	1	38	4	9	(3, 2)	11	2
	22	74	5	1	1	38	4	9	(3, 2)	11	2
	23	64	5	1	1	38	4	9	(3, 2)	11	2
	24	73	5	1	1	38	4	9	(3, 2)	11	2
	26	5	0	0	1	34	1	8	(2, 2)	10	2
	27	4	0	0	1	34	1	8	(2, 2)	10	2

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	28	10	0	0	1	34	1	8	(2, 2)	10	2
	29	54	6	1	1	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	30	3	0	0	1	34	1	8	(2, 2)	10	2
	33	17	4	1	1	34	1	8	(2, 2)	10	2
	35	77	6	1	1	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	36	5	0	0	1	34	1	8	(2, 2)	10	2
	37	80	5	1	1	38	4	9	(3, 2)	11	2
	40	21	7	1	1	34	1	8	(2, 2)	10	2
	44	79	1	1	2	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	47	5	0	0	2	34	1	8	(2, 2)	10	2
	48	76	5	1	2	38	4	9	(3, 2)	11	2
	51	2	0	0	2	34	1	8	(2, 2)	10	2
	53	67	1	1	2	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	54	67	5	1	2	38	4	9	(3, 2)	11	2
	56	85	5	1	2	38	4	9	(3, 2)	11	2
	58	70	2	1	2	26	2	6	(0, 2)	8	0, 1, 2, 3, 4
	60	56	6	1	2	30	2	7	(1, 2)	9	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	64	63	1	1	3	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	65	14	0	0	3	34	1	8	(2, 2)	10	2
	74	4	0	0	3	34	1	8	(2, 2)	10	2
	75	12	0	0	3	34	1	8	(2, 2)	10	2
	78	7	0	0	3	34	1	8	(2, 2)	10	2
	87	73	5	1	4	38	4	9	(3, 2)	11	2
	90	76	5	1	4	38	4	9	(3, 2)	11	2
	91	77	5	1	4	38	4	9	(3, 2)	11	2
	93	71	1	1	4	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	94	70	5	1	4	38	4	9	(3, 2)	11	2
	95	78	5	1	4	38	4	9	(3, 2)	11	2
	96	67	7	1	4	34	1	8	(2, 2)	10	2
	97	71	5	1	4	38	4	9	(3, 2)	11	2
	98	66	5	1	4	38	4	9	(3, 2)	11	2
	99	67	5	1	4	38	4	9	(3, 2)	11	2
9	8	4	0	0	0	34	1	8	(2, 2)	10	2

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	10	12	0	0	0	34	1	8	(2, 2)	10	2
	20	10	0	0	0	34	1	8	(2, 2)	10	2
	21	85	5	1	1	38	4	9	(3, 2)	11	2
	22	74	5	1	1	38	4	9	(3, 2)	11	2
	23	64	5	1	1	38	4	9	(3, 2)	11	2
	24	73	5	1	1	38	4	9	(3, 2)	11	2
	26	5	0	0	1	34	1	8	(2, 2)	10	2
	27	4	0	0	1	34	1	8	(2, 2)	10	2
	28	10	0	0	1	34	1	8	(2, 2)	10	2
	29	54	6	1	1	34	1	8	(2, 2)	10	2
	30	3	0	0	1	34	1	8	(2, 2)	10	2
	33	17	4	1	1	34	1	8	(2, 2)	10	2
	35	77	6	1	1	34	1	8	(2, 2)	10	2
	36	5	0	0	1	34	1	8	(2, 2)	10	2
	37	80	5	1	1	38	4	9	(3, 2)	11	2
	40	21	7	1	1	34	1	8	(2, 2)	10	2
	44	79	1	1	2	30	2	7	(1, 2)	9	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	47	5	0	0	2	34	1	8	(2, 2)	10	2
	48	76	5	1	2	38	4	9	(3, 2)	11	2
	51	2	0	0	2	34	1	8	(2, 2)	10	2
	53	67	1	1	2	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	54	67	5	1	2	38	4	9	(3, 2)	11	2
	56	85	5	1	2	38	4	9	(3, 2)	11	2
	58	70	2	1	2	26	2	6	(0, 2)	8	0, 1, 2, 3, 4
	60	56	6	1	2	34	1	8	(2, 2)	10	2
	64	63	1	1	3	30	2	7	(1, 2)	9	0, 1, 2, 3, 4
	65	14	0	0	3	34	1	8	(2, 2)	10	2
	74	4	0	0	3	34	1	8	(2, 2)	10	2
	75	12	0	0	3	34	1	8	(2, 2)	10	2
	78	7	0	0	3	34	1	8	(2, 2)	10	2
	87	73	5	1	4	38	4	9	(3, 2)	11	2
	90	76	5	1	4	38	4	9	(3, 2)	11	2
	91	77	5	1	4	38	4	9	(3, 2)	11	2
	93	71	1	1	4	30	2	7	(1, 2)	9	0, 1, 2, 3, 4

Table 5.7: Inconsistency between numerical CPLEX and true decision regions (continued)

Iter	Training Instance					Reported		CPLEX	True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Position	Region	Predict
	94	70	5	1	4	38	4	9	(3, 2)	11	2
	95	78	5	1	4	38	4	9	(3, 2)	11	2
	96	67	7	1	4	34	1	8	(2, 2)	10	2
	97	71	5	1	4	38	4	9	(3, 2)	11	2
	98	66	5	1	4	38	4	9	(3, 2)	11	2
	99	67	5	1	4	38	4	9	(3, 2)	11	2

CHAPTER VI

CONCLUDING REMARKS

Throughout this dissertation, the 2020 person-level CPS ASEC health insurance dataset in SAS7BDAT format is converted to feather and CSV formats. The file sizes markedly reduce by 94.02% and 71.31% respectively. Five combinations of health insurance enrollment in employment-based plan (GRP), direct-purchase plan (DIR) and public health insurance (PUB) are considered, leading to five possible classes. All codes are written in Python, well-known for data analysis, except the proposed box classifier in OPL embedded in CPLEX Optimization Studio. A Python class and a pandas DataFrame accessor are introduced so that a method can be called on a DataFrame at any time. All classification models, a Gini-based decision tree and the proposed classifier, are tested on a remote virtual machine to prevent the intervention in local computing resources and also to flexibly configure hardware and operating system. Python 3.13 with the global interpreter lock (GIL) still enabled is built from source. The GitHub repository is also available at https://github.com/songkomkrit/phd.

The proposed box classifier is heavily based on the rigorous formulation of 0-1 MILP problem, and it is very large-scale. Only 100 out of 157,681 noninfant survey participants are randomly selected as a sample of equal class size. Prior to the investigation of 2 contributing factors, 3 out of 184 independent variables are preselected by the SelectKBest using mutual information from a mixture of continuous and categorical features. Compared to the decision tree of multiple depths, the proposed model achieves a high training accuracy and low number of total splits within an hour and a half, though optimality not guaranteed, it constructs the branch-and-cut tree of large size between 6 GB and 7 GB, and it can group together similar categorical values to provide better insight into a selected categorical feature. A limitation of this study includes the lack of high-performance computing (HPC) technology of aggregating multiple computer clusters to efficiently serve massive computation required by the proposed model in the nature of 0-1 MILP. Therefore, further investigation into its approximation algorithm with theoretically derived bound on training accuracy compared to the exact 0-1 MILP model is suggested.

References

Bernstein, D. J., Duif, N., Lange, T., Schwabe, P., and Yang, B.-Y. (2012). High-speed high-security signatures. *Journal of cryptographic engineering*, 2(2):77–89.

Cebula, R. J. (2006). A further analysis of determinants of health insurance coverage. *International Advances in Economic Research*, 12(3):382–389.

Cover, T. M. and Thomas, J. A. T. (2005). *Elements of Information Theory*. John Wiley Sons, Ltd.

Dolinsky, A. and Caputo, R. K. (1997). Psychological and demographic characteristics as determinants of women's health insurance coverage. *Journal of Consumer Affairs*, 31(2):218–237.

Jin, Y., Hou, Z., and Zhang, D. (2016). Determinants of health insurance coverage among people aged 45 and over in china: Who buys public, private and multiple insurance. *PLOS ONE*, 11(8):1–15.

Markowitz, M. A., Gold, M., and Rice, T. (1991). Determinants of health insurance status among young adults. *Medical care*, pages 6–19.

Mulenga, J., Mulenga, M. C., Musonda, K., and Phiri, C. (2021). Examining gender differentials and determinants of private health insurance coverage in zambia. *BMC Health Services Research*, 21(1):1–11.

Rivest, R. L., Shamir, A., and Adleman, L. (1978). A method for obtaining digital signatures and public-key cryptosystems. *Communications of the ACM*, 21(2):120–126.

Ross, B. C. (2014). Mutual information between discrete and continuous data sets. *PLOS ONE*, 9(2):1–5.

Scikit-learn (2024). Decision trees. https://scikit-learn.org/1.5/modules/tree.html. Accessed: 2024-11-18.

APPENDICES

CPLEX Engine Log

```
<<< setup

Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                      3
CPXPARAM_MIP_Limits_Solutions                   1
CPXPARAM_TimeLimit                              86400
CPXPARAM_MIP_Limits_TreeMemory                  204800
Tried aggregator 1 time.
MIP Presolve eliminated 402 rows and 800 columns.
MIP Presolve modified 200 coefficients.
Reduced MIP has 4004 rows, 5507 columns, and 22553 nonzeros.
Reduced MIP has 4643 binaries, 11 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (17.75 ticks)
Found incumbent of value -20.000000 after 0.02 sec. (24.01 ticks)

Root node processing (before b&c):
Real time             =    0.02 sec. (24.25 ticks)
Parallel b&c, 8 threads:
Real time             =    0.00 sec. (0.00 ticks)
Sync time (average)   =    0.00 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =    0.02 sec. (24.25 ticks)

------------------------------
Iteration 1
Bounds on # of cuts = 8 with [3 3 2]
Error = 80 (out of 100 instances)
Accuracy = 20
Solving time = 0.0003894 min (minutes)
Accumulated time = 0.0003894 min (minutes)

Solution status code = 104
LB on error =  -5500
Relative objective gap = 278.999999999

Selected variables:
```

```
Number of selected variables = 0 (0 continuous + 0 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                        3
CPXPARAM_MIP_Limits_Solutions                     1
CPXPARAM_TimeLimit                                86399.976635986328
CPXPARAM_MIP_Limits_TreeMemory                    204800
Probing time = 0.01 sec. (4.62 ticks)
Cover probing fixed 8 vars, tightened 40 bounds.
Clique table members: 11812.
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 8 threads.
Root relaxation solution time = 0.03 sec. (35.79 ticks)

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

*     0+    0                        -20.0000    -5600.0000              ---
0     0    -800.0000   472      -20.0000     -800.0000     1209     ---
0     0    -800.0000   346      -20.0000     Cuts: 512     1987     ---
0     0    -800.0000   651      -20.0000     Cuts: 874     3508     ---
*     0+    0                        -28.0000     -800.0000              ---

GUB cover cuts applied:  29
Clique cuts applied:  10
Cover cuts applied:  51
Implied bound cuts applied:  242
Flow cuts applied:  6
Mixed integer rounding cuts applied:  186
Zero-half cuts applied:  77
Lift and project cuts applied:  7
Gomory fractional cuts applied:  16

Root node processing (before b&c):
Real time             =    1.78 sec. (1803.05 ticks)
Parallel b&c, 8 threads:
Real time             =    0.00 sec. (0.00 ticks)
```

```
Sync time (average)   =    0.00 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =    1.78 sec. (1803.05 ticks)

------------------------------
Iteration 2
Bounds on # of cuts = 8 with [3 3 2]
Error = 72 (out of 100 instances)
Accuracy = 28
Solving time = 0.029740967 min (minutes)
Accumulated time = 0.030130367 min (minutes)

Solution status code = 104
LB on error =  -700
Relative objective gap = 27.571428571

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                       3
CPXPARAM_MIP_Limits_Solutions                    1
CPXPARAM_TimeLimit                               86398.192177978519
CPXPARAM_MIP_Limits_TreeMemory                   204800
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 8 threads.

Nodes                                          Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

*     0+    0                         -31.0000     -717.7485              ---

GUB cover cuts applied:  41
Clique cuts applied:  73
```

```
Cover cuts applied:  433
Implied bound cuts applied:  315
Flow cuts applied:  8
Mixed integer rounding cuts applied:  447
Zero-half cuts applied:  145
Lift and project cuts applied:  13
Gomory fractional cuts applied:  57

Root node processing (before b&c):
Real time              =    0.74 sec. (861.25 ticks)
Parallel b&c, 8 threads:
Real time              =    0.00 sec. (0.00 ticks)
Sync time (average)    =    0.00 sec.
Wait time (average)    =    0.00 sec.
------------
Total (root+branch&cut) =    0.74 sec. (861.25 ticks)

------------------------------
Iteration 3
Bounds on # of cuts = 8 with [3 3 2]
Error = 69 (out of 100 instances)
Accuracy = 31
Solving time = 0.01229578 min (minutes)
Accumulated time = 0.042426147 min (minutes)

Solution status code = 104
LB on error =  -617.482727096
Relative objective gap = 22.1446041

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                   3
CPXPARAM_MIP_Limits_Solutions                1
CPXPARAM_TimeLimit                           86397.45443115235
```

```
CPXPARAM_MIP_Limits_TreeMemory                    204800
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 8 threads.

Nodes                                          Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

*     0+    0                       -36.0000     -657.1275              ---

GUB cover cuts applied:  41
Clique cuts applied:  73
Cover cuts applied:  623
Implied bound cuts applied:  329
Flow cuts applied:  12
Mixed integer rounding cuts applied:  562
Zero-half cuts applied:  191
Lift and project cuts applied:  22
Gomory fractional cuts applied:  108

Root node processing (before b&c):
Real time             =    0.82 sec. (913.50 ticks)
Parallel b&c, 8 threads:
Real time             =    0.00 sec. (0.00 ticks)
Sync time (average)   =    0.00 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =    0.82 sec. (913.50 ticks)

------------------------------
Iteration 4
Bounds on # of cuts = 8 with [3 3 2]
Error = 64 (out of 100 instances)
Accuracy = 36
Solving time = 0.013641048 min (minutes)
Accumulated time = 0.056067196 min (minutes)

Solution status code = 104
LB on error =  -557.127521455
```

```
Relative objective gap = 17.253542263

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                       3
CPXPARAM_MIP_Limits_Solutions                    1
CPXPARAM_TimeLimit                               86396.635968261719
CPXPARAM_MIP_Limits_TreeMemory                   204800
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 8 threads.

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap


*     0+    0                          -38.0000     -626.9345              ---

GUB cover cuts applied:  82
Clique cuts applied:  73
Cover cuts applied:  1063
Implied bound cuts applied:  407
Flow cuts applied:  35
Mixed integer rounding cuts applied:  819
Zero-half cuts applied:  258
Lift and project cuts applied:  22
Gomory fractional cuts applied:  160

Root node processing (before b&c):
Real time             =    1.96 sec. (1928.89 ticks)
Parallel b&c, 8 threads:
Real time             =    0.00 sec. (0.00 ticks)
Sync time (average)   =    0.00 sec.
Wait time (average)   =    0.00 sec.
------------
```

```
Total (root+branch&cut) =    1.96 sec. (1928.89 ticks)

------------------------------
Iteration 5
Bounds on # of cuts = 8 with [3 3 2]
Error = 62 (out of 100 instances)
Accuracy = 38
Solving time = 0.032725952 min (minutes)
Accumulated time = 0.088793148 min (minutes)

Solution status code = 104
LB on error =  -526.934511415
Relative objective gap = 15.498276616

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                    3
CPXPARAM_MIP_Limits_Solutions                 1
CPXPARAM_TimeLimit                            86394.672411132808
CPXPARAM_MIP_Limits_TreeMemory                204800
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 8 threads.

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

0     0     -577.3658   659      -38.0000     Cuts: 836    28237     ---
0     0     -558.5105   640      -38.0000     Cuts: 955    31741     ---
0     0     -540.9147   613      -38.0000     Cuts: 870    34307     ---
0     0     -539.0391   710      -38.0000     Cuts: 924    36234     ---
0     0     -538.9354   762      -38.0000     Cuts: 989    37794     ---
Detecting symmetries...
0     0     -538.8822   778      -38.0000     Cuts: 830    39029     ---
```

```
0      0      -538.8578    826       -38.0000     Cuts: 708     40186      ---
0      0      -538.8409    806       -38.0000     Cuts: 266     40928      ---
0      0      -538.8265    840       -38.0000     Cuts: 601     41623      ---
0      2      -538.8265    827       -38.0000     -538.8265     41623      ---
Elapsed time = 5.26 sec. (5435.47 ticks, tree = 0.02 MB, solutions = 5)
2      4      -532.4711    622       -38.0000     -538.8264     44441      ---
9      9      -530.6872    643       -38.0000     -538.8264     47088      ---
27     20      -521.8493    667       -38.0000     -538.6068     60887      ---
46     20      -531.9657    614       -38.0000     -538.6066     60999      ---
80     68      -509.9472    575       -38.0000     -538.6066    103610      ---
118     57      -528.6696    612       -38.0000     -538.6066     98680      ---
156    138      -490.7266    504       -38.0000     -538.6066    147852      ---
194    169      -486.6126    511       -38.0000     -538.6066    164110      ---
248    209      -484.0715    570       -38.0000     -538.6066    181896      ---
625    468      -387.6828    467       -38.0000     -538.6066    243471      ---
Elapsed time = 8.32 sec. (8694.74 ticks, tree = 6.06 MB, solutions = 5)
1551  1044     infeasible              -38.0000     -538.6066    323452      ---

Performing restart 1


Repeating presolve.
Tried aggregator 1 time.
MIP Presolve eliminated 447 rows and 48 columns.
MIP Presolve modified 2098 coefficients.
Reduced MIP has 3557 rows, 5459 columns, and 21635 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (20.08 ticks)
Tried aggregator 1 time.
MIP Presolve eliminated 1 rows and 0 columns.
MIP Presolve modified 300 coefficients.
Reduced MIP has 3556 rows, 5459 columns, and 21533 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (21.21 ticks)
Represolve time = 0.18 sec. (172.19 ticks)
1603      0      -531.3154    530       -38.0000     Cuts: 989    388606      ---
1603      0      -507.2228    677       -38.0000     Cuts: 989    394828      ---
1603      0      -483.0125    703       -38.0000     Cuts: 989    399749      ---
1603      0      -460.7636    713       -38.0000     Cuts: 989    407166      ---
1603      0      -451.8578    687       -38.0000     Cuts: 989    412425      ---
```

1603	0	-450.6323	805	-38.0000	Cuts:	989	415841	---
1603	0	-432.3823	759	-38.0000	Cuts:	989	423001	---
1603	0	-431.4684	871	-38.0000	Cuts:	989	426280	---
1603	0	-418.8128	830	-38.0000	Cuts:	989	433824	---
1603	0	-417.3207	854	-38.0000	Cuts:	989	437138	998.21%
1603	0	-412.4347	847	-38.0000	Cuts:	989	442602	985.35%
1603	0	-412.0400	919	-38.0000	Cuts:	989	445973	984.32%
1603	0	-411.2439	902	-38.0000	Cuts:	989	449769	980.32%
1603	0	-405.6804	852	-38.0000	Cuts:	989	458674	967.58%
1603	0	-405.2740	821	-38.0000	Cuts:	989	461351	962.76%
1603	0	-400.9631	855	-38.0000	Cuts:	989	468469	952.28%
1603	0	-400.5521	861	-38.0000	Cuts:	989	472372	952.28%
1603	0	-399.9329	893	-38.0000	Cuts:	989	475615	952.28%
1603	0	-397.2191	915	-38.0000	Cuts:	989	483998	944.52%
1603	0	-397.1061	974	-38.0000	Cuts:	989	487153	944.52%
1603	0	-396.3444	963	-38.0000	Cuts:	989	492117	943.01%
1603	0	-395.8637	958	-38.0000	Cuts:	989	496720	939.08%
1603	0	-395.7821	987	-38.0000	Cuts:	989	498869	938.39%
1603	0	-393.1402	932	-38.0000	Cuts:	989	506111	934.58%
1603	0	-393.0317	970	-38.0000	Cuts:	989	508897	934.29%
1603	0	-392.7950	1024	-38.0000	Cuts:	989	513782	933.67%
1603	0	-391.5060	909	-38.0000	Cuts:	989	518934	930.28%
1603	0	-391.4094	932	-38.0000	Cuts:	989	523923	930.02%
1603	0	-390.7816	965	-38.0000	Cuts:	989	530008	928.37%
1603	0	-390.4502	996	-38.0000	Cuts:	989	535960	927.50%
1603	0	-389.7746	975	-38.0000	Cuts:	964	544136	925.72%
1603	0	-389.7179	1028	-38.0000	Cuts:	989	548551	925.57%
1603	0	-389.2127	1004	-38.0000	Cuts:	779	559361	924.24%
1603	0	-389.1541	1044	-38.0000	Cuts:	989	563246	924.09%
1603	0	-388.9571	1041	-38.0000	Cuts:	550	570153	923.57%
1603	0	-388.9327	1102	-38.0000	Cuts:	989	573533	923.51%
1603	0	-388.7011	1102	-38.0000	Cuts:	689	580181	922.90%
1603	0	-388.6569	1153	-38.0000	Cuts:	989	583864	922.78%
1603	2	-388.6569	1138	-38.0000	-388.6569		583864	922.78%
1604	3	-388.2777	1073	-38.0000	-388.2776		587877	921.78%
1605	4	-387.6984	1112	-38.0000	-387.6983		589040	920.26%
1606	5	-387.2199	1098	-38.0000	-387.2194		590656	919.00%
1607	6	-386.8095	1049	-38.0000	-387.0084		594070	918.44%
1609	4	-386.1028	771	-38.0000	-387.0084		595848	918.44%

1610	5	-384.6422	738	-38.0000	-387.0084	598389	918.44%
1612	8	-382.0306	768	-38.0000	-387.0084	613444	918.44%
1615	9	-383.3599	777	-38.0000	-386.9557	622553	918.30%

Elapsed time = 129.55 sec. (136324.17 ticks, tree = 0.02 MB, solutions = 5)

1616	9	-375.8867	788	-38.0000	-386.9557	626524	918.30%
1618	12	-381.5367	781	-38.0000	-386.9557	649547	918.30%
1620	11	-384.0428	927	-38.0000	-386.9557	645526	918.30%
1621	7	-385.0541	787	-38.0000	-386.9557	604066	918.30%
1624	17	-380.8858	736	-38.0000	-386.8091	710376	917.92%
1626	18	-380.7050	773	-38.0000	-386.8091	720185	917.92%
1628	20	-383.5446	949	-38.0000	-386.8091	752988	917.92%
1629	23	-382.1894	814	-38.0000	-386.1685	802390	916.23%
1633	19	-379.8805	765	-38.0000	-386.1685	724806	916.23%
1636	21	-382.9042	965	-38.0000	-386.1685	754400	916.23%

Elapsed time = 144.26 sec. (150551.65 ticks, tree = 0.16 MB, solutions = 5)

1638	23	-380.8078	875	-38.0000	-386.1685	784761	916.23%
1640	30	-378.6604	789	-38.0000	-386.1685	871097	916.23%
1642	33	-382.5092	979	-38.0000	-386.1685	905127	916.23%
1644	28	-369.0237	733	-38.0000	-386.1685	859325	916.23%
1645	37	-371.9556	867	-38.0000	-386.1685	939036	916.23%
1648	39	-371.2651	710	-38.0000	-386.1685	956044	916.23%
1650	41	-372.1191	850	-38.0000	-386.1685	974080	916.23%
1653	42	-379.9721	743	-38.0000	-386.1685	985124	916.23%
1658	49	-377.9725	784	-38.0000	-386.1685	1012953	916.23%
1660	42	-368.8209	739	-38.0000	-386.1685	980397	916.23%

Elapsed time = 158.38 sec. (165820.30 ticks, tree = 0.22 MB, solutions = 5)

1662	46	-371.9569	788	-38.0000	-386.1685	996170	916.23%
1664	45	-378.6304	890	-38.0000	-386.1685	993788	916.23%
1666	48	-362.4336	921	-38.0000	-386.1685	1004351	916.23%
1669	57	-375.2631	783	-38.0000	-386.1685	1054343	916.23%
1672	65	-377.0938	785	-38.0000	-386.1685	1077462	916.23%
1676	56	-370.4028	811	-38.0000	-386.1685	1048798	916.23%
1677	58	-377.8983	718	-38.0000	-386.1685	1057061	916.23%
1680	69	-377.3027	879	-38.0000	-386.1685	1098444	916.23%
1682	73	-377.2401	751	-38.0000	-386.1685	1119275	916.23%
1687	64	-366.9964	711	-38.0000	-386.1685	1081207	916.23%

Elapsed time = 170.66 sec. (179644.29 ticks, tree = 0.33 MB, solutions = 5)

1689	80	-376.0566	805	-38.0000	-386.1685	1152637	916.23%
1692	81	-364.2601	795	-38.0000	-386.1685	1158452	916.23%

```
1698    86     -375.6997   713      -38.0000     -386.1685  1176524   916.23%
1702    78     -367.0278   782      -38.0000     -386.1685  1148330   916.23%
1705    87     -362.6076   808      -38.0000     -386.1685  1186831   916.23%
1709    87     -372.5778   688      -38.0000     -386.1685  1182617   916.23%
1715    91     -361.2418   775      -38.0000     -386.1685  1198439   916.23%
1718    96     -364.3288   787      -38.0000     -386.1685  1229751   916.23%
1722    97     -361.7048   671      -38.0000     -386.1685  1223041   916.23%
1731   101     -371.0484   819      -38.0000     -386.1685  1241877   916.23%
Elapsed time = 181.55 sec. (190828.34 ticks, tree = 0.48 MB, solutions = 5)
1738   101     -352.9145   701      -38.0000     -386.1685  1224916   916.23%
1747   105     -348.2397   651      -38.0000     -386.1685  1226350   916.23%
1751    92     -355.5354   732      -38.0000     -386.1685  1201408   916.23%
1753    98     -363.3957   800      -38.0000     -386.1685  1236017   916.23%
1760   109     -360.8998   699      -38.0000     -386.1685  1258257   916.23%
1766   106     -362.0373   768      -38.0000     -386.1685  1251129   916.23%
1770   138     -369.8963   847      -38.0000     -386.1685  1315878   916.23%
1776   157     -359.2809   751      -38.0000     -386.1685  1371681   916.23%
1780   143     -372.8468   866      -38.0000     -386.1685  1336188   916.23%
1788   159     -357.3907   752      -38.0000     -386.1685  1376458   916.23%
Elapsed time = 192.07 sec. (201530.64 ticks, tree = 1.48 MB, solutions = 5)
1793   165     -351.1548   720      -38.0000     -386.1685  1382812   916.23%
1800   146     -330.0804   647      -38.0000     -386.1685  1313355   916.23%
1809   168     -354.1876   662      -38.0000     -386.1685  1388199   916.23%
1819   169     -347.8706   660      -38.0000     -386.1685  1390338   916.23%
1827   171     -347.0562   700      -38.0000     -386.1685  1392341   916.23%
1838   198     -359.3410   735      -38.0000     -386.1685  1468649   916.23%
1844   189     -316.1421   609      -38.0000     -386.1685  1413172   916.23%
1856   184     -366.0754   822      -38.0000     -386.1685  1431628   916.23%
1862   177     -342.0989   643      -38.0000     -386.1685  1401987   916.23%
1872   185     -368.7856   775      -38.0000     -386.1685  1433055   916.23%
Elapsed time = 202.84 sec. (212543.16 ticks, tree = 2.11 MB, solutions = 5)
1886   204     -348.5624   768      -38.0000     -386.1685  1470065   916.23%
1896   187     -367.8768   775      -38.0000     -386.1685  1439100   916.23%
1910   263     -366.6514   725      -38.0000     -386.1685  1563807   916.23%
1917   226     -366.2143   745      -38.0000     -386.1685  1526100   916.23%
1936   223     -329.7481   750      -38.0000     -386.1685  1508197   916.23%
1943   280     -352.0908   798      -38.0000     -386.1685  1611855   916.23%
1954   306     -346.5994   704      -38.0000     -386.1685  1668764   916.23%
1963   266     -359.3957   727      -38.0000     -386.1685  1578568   916.23%
```

1976	227	-330.0316	709	-38.0000	-386.1685	1517288	916.23%
1996	304	-332.9077	756	-38.0000	-386.1685	1652826	916.23%

Elapsed time = 212.95 sec. (223101.71 ticks, tree = 5.77 MB, solutions = 5)

2005	237	-359.0799	637	-38.0000	-386.1685	1547380	916.23%
2023	289	-351.0669	792	-38.0000	-386.1685	1631819	916.23%
2045	312	-332.4457	739	-38.0000	-386.1685	1662091	916.23%
2068	366	-350.4486	785	-38.0000	-386.1685	1774184	916.23%
2081	393	-327.5920	631	-38.0000	-386.1685	1810141	916.23%
2099	326	-322.0228	695	-38.0000	-386.1685	1696440	916.23%
2119	349	-325.3107	627	-38.0000	-386.1685	1722349	916.23%
2140	448	-321.3074	722	-38.0000	-386.1685	1913614	916.23%
2160	460	-315.9675	684	-38.0000	-386.1685	1927645	916.23%
2227	375	-329.5555	813	-38.0000	-386.1685	1801495	916.23%

Elapsed time = 225.67 sec. (235995.28 ticks, tree = 6.47 MB, solutions = 5)

2329	554	-274.9106	575	-38.0000	-386.1685	2020145	916.23%
2462	603	-208.4551	608	-38.0000	-386.1685	2106858	916.23%
2643	662	-287.5155	621	-38.0000	-386.1685	2198449	916.23%
2816	632	-274.9940	683	-38.0000	-386.1685	2159172	916.23%
2986	735	-213.5904	523	-38.0000	-386.1685	2277454	916.23%
3306	787	-211.7584	632	-38.0000	-385.3111	2315535	913.98%
3607	1286	-201.8962	558	-38.0000	-385.3111	2674488	913.98%
3977	1303	-183.7525	692	-38.0000	-385.3111	2693379	913.98%
4008	1540	-376.5161	957	-38.0000	-385.3111	2835562	913.98%
4055	1700	-376.8232	922	-38.0000	-385.3111	2930975	913.98%

Elapsed time = 265.35 sec. (274668.79 ticks, tree = 65.53 MB, solutions = 5)

4113	1703	-375.8357	891	-38.0000	-385.3111	2941519	913.98%
4283	2263	-129.2319	583	-38.0000	-384.4635	3322625	911.75%
4472	2267	-374.2307	1055	-38.0000	-384.4635	3388151	911.75%
4510	2280	-365.4293	795	-38.0000	-384.4635	3426661	911.75%
4538	2416	-346.9335	718	-38.0000	-381.9426	3507655	905.11%
4576	2480	-361.8407	815	-38.0000	-381.9426	3618609	905.11%
4615	2528	-373.4181	888	-38.0000	-381.9426	3742100	905.11%
4658	2532	-342.0634	836	-38.0000	-381.9426	3734502	905.11%
4699	2533	-365.4533	944	-38.0000	-381.9426	3763000	905.11%
4747	2657	-310.5418	677	-38.0000	-381.9426	4014791	905.11%

Elapsed time = 303.11 sec. (313289.88 ticks, tree = 111.76 MB, solutions = 5)

4802	2620	-349.3655	890	-38.0000	-381.9426	3957330	905.11%
4871	2755	-323.3668	697	-38.0000	-381.9426	4199276	905.11%
4946	2741	-290.9565	601	-38.0000	-381.9426	4189091	905.11%

5043	2816	-273.6839	761	-38.0000	-381.9426	4291508	905.11%
5155	2962	-201.2710	658	-38.0000	-381.9426	4460142	905.11%
5291	2981	-169.8593	604	-38.0000	-381.9426	4478921	905.11%
5466	3076	-203.9541	682	-38.0000	-381.9426	4584024	905.11%
5694	3180	-135.7850	678	-38.0000	-381.9426	4698677	905.11%
6097	3555	-75.2412	434	-38.0000	-381.9426	4847836	905.11%
6335	3538	-100.6562	464	-38.0000	-381.9426	4949312	905.11%

Elapsed time = 342.63 sec. (351762.11 ticks, tree = 158.31 MB, solutions = 5)

6614	4051	-82.9797	391	-38.0000	-381.9426	5198382	905.11%
7157	4043	-93.9551	441	-38.0000	-381.9426	5261948	905.11%
7752	4029	-193.8106	526	-38.0000	-381.9426	5254080	905.11%
7876	4590	-83.9348	406	-38.0000	-381.8931	5514496	904.98%
7902	4881	-379.3565	919	-38.0000	-381.8926	5595047	904.98%
7940	5145	-286.1287	658	-38.0000	-380.8071	5682204	902.12%
8002	4691	-379.3689	774	-38.0000	-380.6354	5544630	901.67%
8035	5148	-364.5840	753	-38.0000	-380.6354	5716992	901.67%
8098	5346	-324.6925	717	-38.0000	-379.9667	5809066	899.91%
8209	5380	-263.0652	689	-38.0000	-379.9667	5827011	899.91%

Elapsed time = 383.55 sec. (391445.00 ticks, tree = 250.41 MB, solutions = 5)

8407	5393	-359.8021	721	-38.0000	-379.9667	5914698	899.91%
8481	5521	-262.1683	689	-38.0000	-379.9667	6008749	899.91%
8682	5483	-357.5335	722	-38.0000	-379.9667	6039212	899.91%
8840	5744	-352.5118	627	-38.0000	-379.9667	6188503	899.91%
9256	5975	-93.5178	383	-38.0000	-379.9667	6283362	899.91%
9630	6102	-222.7763	518	-38.0000	-379.9667	6388913	899.91%
9957	6395	-332.9427	599	-38.0000	-379.9667	6566131	899.91%
10206	6704	-102.7602	493	-38.0000	-379.9667	6620570	899.91%
10687	6744	-356.8449	804	-38.0000	-379.9667	6676558	899.91%
10892	7279	-141.4255	485	-38.0000	-379.9667	6824257	899.91%

Elapsed time = 424.74 sec. (430070.66 ticks, tree = 348.74 MB, solutions = 5)

11285	7549	-266.8955	713	-38.0000	-379.9667	6935942	899.91%
11952	8078	-81.0221	475	-38.0000	-379.9667	7048892	899.91%
12136	8219	-376.5899	831	-38.0000	-379.7943	7146826	899.46%
12316	8696	-376.1854	831	-38.0000	-379.5824	7253016	898.90%
12762	9331	-109.6829	395	-38.0000	-379.5824	7366582	898.90%
13127	9413	-307.3537	678	-38.0000	-379.4554	7421367	898.57%
13190	9725	-370.0417	752	-38.0000	-379.4554	7491216	898.57%
13369	10087	-365.0055	759	-38.0000	-379.4554	7647384	898.57%
13522	9992	-149.8716	574	-38.0000	-379.3906	7584555	898.40%

```
13675 10455     -169.6634   556      -38.0000     -379.3906  7707912  898.40%
Elapsed time = 472.46 sec. (468453.20 ticks, tree = 464.06 MB, solutions = 5)
13959 10554     -275.5156   638      -38.0000     -379.3906  7826355  898.40%
14081 10676     -330.6031   587      -38.0000     -379.3841  7853249  898.38%
14380 10903     -299.8063   554      -38.0000     -379.2996  7908540  898.16%
14811 10991      -84.2419   244      -38.0000     -379.2886  7914970  898.13%
15473 11856      -43.7849   209      -38.0000     -379.2886  8097559  898.13%
15621 11659     -375.0829   765      -38.0000     -379.2886  8079509  898.13%
15745 12045     -279.4488   234      -38.0000     -379.2886  8159239  898.13%
16259 12480     -122.9856   334      -38.0000     -379.2886  8247673  898.13%
16560 12619     -150.5545   539      -38.0000     -379.2386  8302917  898.00%
16678 12987     -260.3273   396      -38.0000     -378.8563  8406230  896.99%
Elapsed time = 525.90 sec. (506688.39 ticks, tree = 537.86 MB, solutions = 5)
16832 13408     -360.3564   681      -38.0000     -378.8563  8512516  896.99%
17110 13421     -347.1104   577      -38.0000     -378.7315  8526769  896.66%
17190 13641     -337.1913   715      -38.0000     -378.5983  8577198  896.31%
17403 13718     -266.2754   489      -38.0000     -378.5983  8642161  896.31%
17723 13869     -246.2897   615      -38.0000     -378.5983  8701973  896.31%
17846 14453     -147.7591   476      -38.0000     -378.5983  8901628  896.31%
18013 14743     -257.4287   619      -38.0000     -378.5983  9008331  896.31%
18451 14774     -193.0102   557      -38.0000     -378.5983  9013834  896.31%
18659 14808     -112.1777   501      -38.0000     -378.5983  9017455  896.31%
18954 15194     -365.5685   865      -38.0000     -378.5983  9123572  896.31%
Elapsed time = 577.52 sec. (546429.72 ticks, tree = 545.80 MB, solutions = 5)
18993 14989     -304.6462   216      -38.0000     -378.5190  9079117  896.10%
19220 15840     -359.2220   537      -38.0000     -378.5190  9298493  896.10%
19362 15500     -367.9160   862      -38.0000     -378.3778  9199784  895.73%
19647 16099     -337.1348   625      -38.0000     -378.2779  9416366  895.47%
19967 16207     -348.9415   288      -38.0000     -378.2779  9475112  895.47%
20375 16345     -375.7467   838      -38.0000     -378.2215  9569876  895.32%
20568 16421     -210.0809   171      -38.0000     -378.2029  9586501  895.27%
20898 16905      -48.9183   177      -38.0000     -378.1858  9664318  895.23%
21209 17362      -43.6742   267      -38.0000     -378.1858  9772573  895.23%
21460 17380     -195.1753   181      -38.0000     -378.1382  9776799  895.10%
Elapsed time = 628.76 sec. (585005.60 ticks, tree = 564.44 MB, solutions = 5)
21731 17569     -176.2266   368      -38.0000     -378.1382  9846289  895.10%
22006 18252     -234.4369   589      -38.0000     -378.1353 10008342  895.09%
22183 18306     -306.6087   349      -38.0000     -378.1353  9991426  895.09%
22423 18469     -121.7009   505      -38.0000     -378.1353 10072247  895.09%
```

```
22692 18987     -121.6388   336      -38.0000      -378.1353 10213880  895.09%
22850 19137      -56.8695   394      -38.0000      -378.1353 10254885  895.09%
22918 19013     -364.3899   709      -38.0000      -378.0981 10236729  894.99%
23147 19464     -325.3539   713      -38.0000      -377.9287 10374695  894.55%
23527 19550     -169.3183   533      -38.0000      -377.9287 10393813  894.55%
24049 19625     -364.2002   903      -38.0000      -377.8836 10371003  894.43%
Elapsed time = 682.61 sec. (623723.92 ticks, tree = 682.22 MB, solutions = 5)
24686 20421     -368.3340   750      -38.0000      -377.8294 10657403  894.29%
25245 19621     -341.1563   713      -38.0000      -377.8294 10466998  894.29%
25810 20807     -353.1728   676      -38.0000      -377.8294 10767293  894.29%
26049 21383     -358.5244   487      -38.0000      -377.8294 10845444  894.29%
26370 21135     -277.1734   655      -38.0000      -377.7041 10818422  893.96%
26824 21172     -182.8045   538      -38.0000      -377.6195 10821038  893.74%
27218 22670     -296.3888   360      -38.0000      -377.6195 11004288  893.74%
27628 22783     -189.3246   127      -38.0000      -377.6147 11054059  893.72%
28136 22825     -270.7104   612      -38.0000      -377.6147 11112939  893.72%
28294 24138     -209.7610   529      -38.0000      -377.6147 11307267  893.72%
Elapsed time = 734.91 sec. (662090.80 ticks, tree = 797.77 MB, solutions = 5)
28605 23711     -234.1514   552      -38.0000      -377.6147 11253825  893.72%
28840 24553     -268.2504   475      -38.0000      -377.5816 11391896  893.64%
29426 24982     -166.5687   513      -38.0000      -377.5816 11485504  893.64%
29687 25483     -371.1550   894      -38.0000      -377.5816 11577943  893.64%
30202 25692     -274.5559   499      -38.0000      -377.4552 11622202  893.30%
30909 25657      -63.7559   371      -38.0000      -377.4257 11604346  893.23%
31597 25853     -118.5099   565      -38.0000      -377.4257 11717188  893.23%
32092 26336     -181.8973   511      -38.0000      -377.4257 11767598  893.23%
33050 26745      -46.3389   148      -38.0000      -377.4257 11832881  893.23%
33558 27309      -53.9421    87      -38.0000      -377.3971 11887058  893.15%
Elapsed time = 781.18 sec. (700363.36 ticks, tree = 1010.72 MB, solutions = 5)
33666 27434     -282.0341   190      -38.0000      -377.2214 11958972  892.69%
* 33853+29275                          -39.0000      -377.1435            867.03%
33922 29276     -367.3141   816      -39.0000      -377.1435 12240781  867.03%
33978 29609     -373.9386   762      -39.0000      -377.1435 12286072  867.03%
34107 29321     -272.3192   625      -39.0000      -377.1435 12257306  867.03%

GUB cover cuts applied:  745
Clique cuts applied:  45
Cover cuts applied:  3303
Implied bound cuts applied:  47
```

```
Flow cuts applied:  81
Mixed integer rounding cuts applied:  882
Zero-half cuts applied:  110
Lift and project cuts applied:  6
Gomory fractional cuts applied:  196

Root node processing (before b&c):
  Real time             =    5.07 sec. (5253.09 ticks)
Parallel b&c, 8 threads:
  Real time             =  792.79 sec. (713089.45 ticks)
  Sync time (average)   =   91.30 sec.
  Wait time (average)   =    0.07 sec.
                          ------------
Total (root+branch&cut) =  797.86 sec. (718342.54 ticks)

------------------------------
Iteration 6
Bounds on # of cuts = 8 with [3 3 2]
Error = 61 (out of 100 instances)
Accuracy = 39
Solving time = 13.297700484 min (minutes)
Accumulated time = 13.386493632 min (minutes)

Solution status code = 104
LB on error =  -277.143152611
Relative objective gap = 8.670337246

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                       3
CPXPARAM_MIP_Limits_Solutions                    1
CPXPARAM_TimeLimit                               85596.810382080075
CPXPARAM_MIP_Limits_TreeMemory                   204800
```

```
Nodes                                              Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

34184 30011    infeasible             -39.0000     -377.1432 12462046  867.03%
Elapsed time = 0.56 sec. (7.69 ticks, tree = 1131.55 MB, solutions = 6)
34185 30011    infeasible             -39.0000     -377.1432 12463576  867.03%
34186 30012     -353.1274   307       -39.0000     -377.1432 12467117  867.03%
34230 30050     -240.2890   140       -39.0000     -377.1432 12469248  867.03%
34284 30101      -96.2412    68       -39.0000     -377.1432 12469654  867.03%
34322 30026     -310.4203   254       -39.0000     -377.1432 12474494  867.03%
34358 30062     -208.3211   168       -39.0000     -377.1432 12474783  867.03%
34418 30117      -61.5243    49       -39.0000     -377.1432 12474986  867.03%
34429 30013     -375.1626   767       -39.0000     -377.1432 12465551  867.03%
34430 30013     -368.5689   712       -39.0000     -377.1432 12480749  867.03%
34467 30044     -274.8883   182       -39.0000     -377.1369 12485663  867.02%
Elapsed time = 4.67 sec. (3790.87 ticks, tree = 1118.48 MB, solutions = 6)
34559 30016     -375.0799   850       -39.0000     -377.1369 12488423  867.02%
34566 30025     -347.9018   626       -39.0000     -376.9781 12489041  866.61%
34577 30032     -332.5967   607       -39.0000     -376.9781 12490820  866.61%
34601 30027     -337.4018   605       -39.0000     -376.9781 12498141  866.61%
34627 30041     -305.9294   499       -39.0000     -376.9781 12501938  866.61%
34686 30147     -296.6126   233       -39.0000     -376.9781 12501312  866.61%
34810 30028     -351.9984   446       -39.0000     -376.9781 12506723  866.61%
34871 30070     -210.9115   477       -39.0000     -376.9781 12496496  866.61%
34894 30030     -347.0129   721       -39.0000     -376.9781 12516063  866.61%
34921 30128     -340.5311   403       -39.0000     -376.9781 12501487  866.61%
Elapsed time = 18.01 sec. (13637.71 ticks, tree = 1129.36 MB, solutions = 6)
35000 30164     -248.6996   190       -39.0000     -376.9781 12503763  866.61%
35127 30084     -205.3721   505       -39.0000     -376.9781 12522308  866.61%
35293 30114     -133.2772   471       -39.0000     -376.9781 12523058  866.61%
35359 30236     -342.9975   706       -39.0000     -376.9781 12518300  866.61%
35553 30295     -154.2894   114       -39.0000     -376.9781 12510201  866.61%
35761 30483      -66.1665    53       -39.0000     -376.9781 12512438  866.61%
35798 30258     -297.3622   651       -39.0000     -376.9781 12521841  866.61%
35816 30266     -281.3269   625       -39.0000     -376.9781 12523129  866.61%
35843 30276     -256.0856   595       -39.0000     -376.9744 12523344  866.60%
35885 30140     -302.2962   240       -39.0000     -376.9744 12517050  866.60%
Elapsed time = 30.67 sec. (23289.65 ticks, tree = 1133.67 MB, solutions = 6)
36002 30180     -252.7491   441       -39.0000     -376.9744 12529649  866.60%
```

```
36062 30299     -206.5953   589       -39.0000     -376.9744 12527129  866.60%
36101 30230      -57.4126   281       -39.0000     -376.9744 12532623  866.60%
36126 30319     -159.6736   546       -39.0000     -376.9744 12528123  866.60%
36145 30340     -344.3312   457       -39.0000     -376.9744 12533604  866.60%
36233 30409     -163.6412   356       -39.0000     -376.9744 12535025  866.60%
36303 30347      -91.1935   479       -39.0000     -376.9744 12529582  866.60%
36329 30235     -375.3955   857       -39.0000     -376.9744 12539899  866.60%
36545 30368        cutoff             -39.0000     -376.9744 12531654  866.60%
36575 30265     -348.5818   255       -39.0000     -376.9744 12541452  866.60%
Elapsed time = 42.20 sec. (33038.41 ticks, tree = 1127.58 MB, solutions = 6)
36709 30470     -351.3221   624       -39.0000     -376.9744 12544142  866.60%
36729 30559     -215.9049   649       -39.0000     -376.9744 12544298  866.60%
36812 30436     -161.8911   120       -39.0000     -376.9744 12548856  866.60%
36944 30486     -328.9821   597       -39.0000     -376.9744 12550670  866.60%
37174 30492     -322.6494   608       -39.0000     -376.9744 12552363  866.60%
37271 30718     -149.7022   112       -39.0000     -376.9744 12556065  866.60%
37335 30604     -117.6572   523       -39.0000     -376.9744 12548367  866.60%
37361 30612      -97.8061   497       -39.0000     -376.9744 12549204  866.60%
37508 30622      -74.8865   483       -39.0000     -376.9744 12549545  866.60%
37547 30284     -269.1983   676       -39.0000     -376.9744 12570795  866.60%
Elapsed time = 56.00 sec. (42712.64 ticks, tree = 1132.84 MB, solutions = 6)
37587 30639      -46.6761   404       -39.0000     -376.9744 12551100  866.60%
37639 30414     -311.7083   637       -39.0000     -376.9744 12561840  866.60%
37916 30226      -75.1134    38       -39.0000     -376.9744 12586701  866.60%
37975 30522     -298.5992   190       -39.0000     -376.9744 12567952  866.60%
38358 30734      -49.6809    34       -39.0000     -376.9744 12573259  866.60%
38425 30896     -312.8846   395       -39.0000     -376.9744 12576993  866.60%
38560 30651     -351.1738   707       -39.0000     -376.9744 12567726  866.60%
38703 30659     -338.3736   682       -39.0000     -376.9744 12569044  866.60%
38722 30923     -251.4943   422       -39.0000     -376.9744 12578618  866.60%
38807 30678     -300.9916   641       -39.0000     -376.9744 12570330  866.60%
Elapsed time = 69.11 sec. (52474.66 ticks, tree = 1168.75 MB, solutions = 6)
38865 30114     -364.9152   785       -39.0000     -376.9744 12605868  866.60%
39094 30118     -364.5336   776       -39.0000     -376.9744 12608499  866.60%
39163 30390     -290.9313   188       -39.0000     -376.9744 12593666  866.60%
39318 30330     -128.7170   102       -39.0000     -376.9744 12608320  866.60%
39378 30824     -371.6508   666       -39.0000     -376.9744 12583385  866.60%
39448 30859     -235.6664   169       -39.0000     -376.9744 12587080  866.60%
39572 30207     -115.2196   106       -39.0000     -376.9744 12620071  866.60%
```

```
39664 30963     -184.5348   344       -39.0000      -376.9744 12600785  866.60%
39767 30781     -243.6394   154       -39.0000      -376.9744 12609310  866.60%
39849 30937     -367.9700   804       -39.0000      -376.9744 12597338  866.60%
Elapsed time = 80.41 sec. (62223.15 ticks, tree = 1187.62 MB, solutions = 6)
39854 30851     -372.7405   686       -39.0000      -376.9744 12613720  866.60%
39993 30935     -102.8985    77       -39.0000      -376.9744 12616877  866.60%
40140 30982     -256.2504   319       -39.0000      -376.9744 12605444  866.60%
40214 31050      -74.6662   160       -39.0000      -376.9744 12606445  866.60%
40237 30486     -373.3192   818       -39.0000      -376.9744 12620511  866.60%
40365 30487     -371.8640   807       -39.0000      -376.9744 12623950  866.60%
40369 31131     -374.6936   763       -39.0000      -376.9744 12621218  866.60%
40456 31135     -198.9005   131       -39.0000      -376.9744 12617239  866.60%
40555 30500     -355.6002   607       -39.0000      -376.9744 12631140  866.60%
40570 30508     -331.8984   543       -39.0000      -376.9744 12632773  866.60%
Elapsed time = 92.34 sec. (72321.10 ticks, tree = 1149.15 MB, solutions = 6)
40596 30518     -328.9640   539       -39.0000      -376.9744 12633058  866.60%
40632 30271     -259.0082   190       -39.0000      -376.9744 12650779  866.60%
40800 31223      -90.5794    81       -39.0000      -376.9744 12635395  866.60%
41073 31344      -64.5276    40       -39.0000      -376.9744 12637685  866.60%
41160 30618     -133.3406   487       -39.0000      -376.9744 12643767  866.60%
41210 31110     -356.1415   734       -39.0000      -376.9744 12623652  866.60%
41230 30356     -355.0434   236       -39.0000      -376.9744 12664838  866.60%
41364 31124     -323.7738   674       -39.0000      -376.9744 12626631  866.60%
41379 31356     -369.4440   735       -39.0000      -376.9744 12647780  866.60%
41481 30734     -138.1924    86       -39.0000      -376.9744 12656975  866.60%
Elapsed time = 104.01 sec. (81980.95 ticks, tree = 1160.34 MB, solutions = 6)
41544 30398     -298.4723   615       -39.0000      -376.9744 12669908  866.60%
41678 31417     -241.3441   167       -39.0000      -376.9744 12654919  866.60%
41866 31505      -61.6078    64       -39.0000      -376.9744 12655794  866.60%
41914 31163     -244.9421   559       -39.0000      -376.9744 12639460  866.60%
42050 31172     -220.4289   522       -39.0000      -376.9744 12640470  866.60%
42082 30440     -203.7039   545       -39.0000      -376.9744 12674888  866.60%
42117 30505     -307.1978   643       -39.0000      -376.9744 12694878  866.60%
42157 30458     -162.6077   487       -39.0000      -376.9744 12676762  866.60%
42257 31346     -321.7987   248       -39.0000      -376.9744 12666744  866.60%
42771 31228     -124.3631    93       -39.0000      -376.9744 12686599  866.60%
Elapsed time = 119.11 sec. (94489.24 ticks, tree = 1192.42 MB, solutions = 6)
43224 31270     -374.6367   958       -39.0000      -376.9744 12694136  866.60%
43751 33045     -161.2916   114       -39.0000      -376.9744 12987648  866.60%
```

```
44530 30774     -150.7804   111      -39.0000     -376.9744 12718084  866.60%
44812 30814     -374.2969  1033      -39.0000     -376.9744 12725929  866.60%
45132 30671        cutoff            -39.0000     -376.9744 12724888  866.60%
45505 31494     -360.9840   699      -39.0000     -376.9744 12709907  866.60%
45992 31897      -85.7831    53      -39.0000     -376.9744 12902866  866.60%
46284 35065     -111.8791    76      -39.0000     -376.9744 13253046  866.60%
46578 31053     -356.1008   650      -39.0000     -376.9744 12774822  866.60%
46906 31958     -274.4820   382      -39.0000     -376.9744 12935080  866.60%
Elapsed time = 164.80 sec. (133139.60 ticks, tree = 1235.78 MB, solutions = 6)
47493 31337     -291.1340   219      -39.0000     -376.9744 12792486  866.60%
48138 31430     -374.7112  1029      -39.0000     -376.9744 12799082  866.60%
48546 32033     -116.6233   179      -39.0000     -376.9194 12782627  866.46%
49011 32202     -357.4841   370      -39.0000     -376.9194 12958830  866.46%
50019 32432     -103.9418    68      -39.0000     -376.9194 12967930  866.46%
50531 31080     -370.9851   885      -39.0000     -376.9194 12828929  866.46%
* 50701+31549                          -40.0000     -376.9194           842.30%
51048 32626     -160.4344   119      -40.0000     -376.9194 12988233  842.30%
51323 33736     -344.6369   244      -40.0000     -376.9194 13106949  842.30%
51999 37235     -345.6706   331      -40.0000     -376.9194 13626666  842.30%
52188 31438     -349.4261   701      -40.0000     -376.9194 12876494  842.30%
Elapsed time = 209.24 sec. (171662.93 ticks, tree = 1199.03 MB, solutions = 7)
52481 37432     -201.6757   314      -40.0000     -376.9194 13648219  842.30%
53422 35758     -365.5130   684      -40.0000     -376.9194 13371629  842.30%
53912 37682     -130.6639    94      -40.0000     -376.9194 13667768  842.30%
54122 34391     -222.5263   261      -40.0000     -376.9194 13156341  842.30%
54537 34575     -118.8445    76      -40.0000     -376.9194 13161634  842.30%
54944 32867     -274.5121   285      -40.0000     -376.9194 13066188  842.30%
55210 36351     -126.9557    87      -40.0000     -376.9194 13427861  842.30%
55473 36429     -261.6947   186      -40.0000     -376.9194 13441222  842.30%
55684 34630     -361.6861   651      -40.0000     -376.9194 13188259  842.30%
56056 31799     -294.4002   652      -40.0000     -376.9194 12963851  842.30%
Elapsed time = 253.04 sec. (209922.64 ticks, tree = 1190.36 MB, solutions = 7)
56741 31813     -374.9630   885      -40.0000     -376.9194 12984867  842.30%
57071 36555     -349.2594   626      -40.0000     -376.9194 13480838  842.30%
57695 31966     -342.6780   723      -40.0000     -376.9194 13006011  842.30%
58149 32052     -133.2492    96      -40.0000     -376.9194 13020291  842.30%
58577 36670     -319.4597   209      -40.0000     -376.9194 13512903  842.30%
59334 38194    infeasible            -40.0000     -376.9194 13776794  842.30%
59411 36778     -351.9628   635      -40.0000     -376.9194 13531178  842.30%
```

```
59775 33722     -371.4617   918      -40.0000     -376.9194 13181426  842.30%
59948 36900     -366.2275   661      -40.0000     -376.9194 13549234  842.30%
60447 32460     -335.7909   735      -40.0000     -376.9194 13080118  842.30%
Elapsed time = 296.23 sec. (248581.39 ticks, tree = 1274.28 MB, solutions = 7)
60791 37101     -185.5764   181      -40.0000     -376.9194 13570876  842.30%
61392 34217     -374.0933   734      -40.0000     -376.9194 13219253  842.30%
62039 36439     -363.2180   698      -40.0000     -376.9194 13336882  842.30%
62196 36566      -46.5830   229      -40.0000     -376.9194 13345567  842.30%
62482 34472     -340.0144   758      -40.0000     -376.9194 13248238  842.30%
Began writing nodes to disk (directory ./cpxhGkJOU created)

GUB cover cuts applied:  872
Clique cuts applied:  53
Cover cuts applied:  3794
Implied bound cuts applied:  59
Flow cuts applied:  95
Mixed integer rounding cuts applied:  1264
Zero-half cuts applied:  118
Lift and project cuts applied:  8
Gomory fractional cuts applied:  197

Root node processing (before b&c):
Real time             =    0.00 sec. (0.68 ticks)
Parallel b&c, 8 threads:
Real time             =  316.13 sec. (270209.62 ticks)
Sync time (average)   =   21.13 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  316.14 sec. (270210.30 ticks)

------------------------------
Iteration 7
Bounds on # of cuts = 8 with [3 3 2]
Error = 60 (out of 100 instances)
Accuracy = 40
Solving time = 5.268966785 min (minutes)
Accumulated time = 18.655460417 min (minutes)

Solution status code = 104
```

```
LB on error =  -276.833555011
Relative objective gap = 8.420838875

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                        3
CPXPARAM_MIP_Limits_Solutions                     1
CPXPARAM_TimeLimit                                85280.672374999995
CPXPARAM_MIP_Limits_TreeMemory                    204800

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

62493 56328     -371.5512   875       -40.0000     -376.8336 16793405  842.08%
Elapsed time = 1.28 sec. (381.47 ticks, tree = 2553.13 MB, solutions = 7)
Nodefile size = 505.19 MB (457.73 MB after compression)
62494 56329     -371.1453   802       -40.0000     -376.8336 16795022  842.08%
62497 56331     -371.0317   798       -40.0000     -376.8336 16796271  842.08%
62498 56328     -368.1504   812       -40.0000     -376.8336 16797169  842.08%
62512 56334     -374.4435   690       -40.0000     -376.8336 16798167  842.08%
62525 56343     -367.3256   732       -40.0000     -376.8336 16801668  842.08%
62532 56335     -369.7631   729       -40.0000     -376.8336 16799811  842.08%
62542 56346    infeasible             -40.0000     -376.8336 16803611  842.08%
62547 56350     -365.8593   652       -40.0000     -376.8336 16804496  842.08%
62560 56356     -364.8589   634       -40.0000     -376.8336 16805402  842.08%
62618 56340     -373.4930   705       -40.0000     -376.8336 16804652  842.08%
Elapsed time = 5.50 sec. (4460.10 ticks, tree = 2546.50 MB, solutions = 7)
Nodefile size = 505.19 MB (457.73 MB after compression)
62639 56342     -376.2051   828       -40.0000     -376.8205 16808904  842.05%
62665 56385     -373.6476   439       -40.0000     -376.8205 16811958  842.05%
62722 56376     -285.1413   212       -40.0000     -376.8205 16814049  842.05%
62904 56365     -320.2108   319       -40.0000     -376.8205 16832674  842.05%
62969 56414     -207.5316   159       -40.0000     -376.8205 16836614  842.05%
63094 56358     -361.8225   455       -40.0000     -376.8205 16829520  842.05%
```

```
63139 56390     -350.5564   411       -40.0000     -376.8205 16833177  842.05%
63164 56347     -366.7584   820       -40.0000     -376.8205 16827937  842.05%
63232 56547     -261.9177   265       -40.0000     -376.8205 16828650  842.05%
63383 56506     -372.3550   659       -40.0000     -376.8205 16845155  842.05%
Elapsed time = 17.85 sec. (15002.70 ticks, tree = 2538.21 MB, solutions = 7)
Nodefile size = 505.19 MB (457.73 MB after compression)
63431 56370     -361.1593   662       -40.0000     -376.8205 16836599  842.05%
63518 56528     -366.3616   580       -40.0000     -376.8205 16851365  842.05%
63551 56668     -372.7898   614       -40.0000     -376.8205 16838522  842.05%
63617 56356    infeasible             -40.0000     -376.8205 16847550  842.05%
63657 56433     -373.2525   857       -40.0000     -376.5778 16842129  841.44%
63720 56584    infeasible             -40.0000     -376.5778 16866006  841.44%
63742 56708     -347.8130   343       -40.0000     -376.5778 16851562  841.44%
63817 56407     -372.9694   713       -40.0000     -376.5778 16853277  841.44%
63875 56438     -336.4001   379       -40.0000     -376.5778 16856671  841.44%
63937 56457     -370.4856   719       -40.0000     -376.5778 16855716  841.44%
Elapsed time = 29.24 sec. (24884.76 ticks, tree = 2542.06 MB, solutions = 7)
Nodefile size = 505.19 MB (457.73 MB after compression)
63986 56760     -361.2265   352       -40.0000     -376.5778 16863808  841.44%
* 64088+56788                           -42.0000     -376.5778            796.61%
64161 56427     -308.4527   287       -42.0000     -376.5778 16861750  796.61%
64305 56426     -364.4031   448       -42.0000     -376.5778 16867050  796.61%
64344 56429        cutoff             -42.0000     -376.5778 16870294  796.61%
64408 56433     -361.1858   402       -42.0000     -376.5778 16864366  796.61%
64514 56592     -369.9594   867       -42.0000     -376.5778 16880737  796.61%
64661 56555     -117.7107    86       -42.0000     -376.5778 16881851  796.61%
64713 56603     -366.8417   779       -42.0000     -376.5778 16886930  796.61%
64780 56605     -366.4698   401       -42.0000     -376.5778 16885487  796.61%
64920 56444     -257.3129   304       -42.0000     -376.5778 16880818  796.61%
Elapsed time = 40.45 sec. (34952.40 ticks, tree = 2527.61 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
65008 56483     -373.2735   748       -42.0000     -376.5778 16879719  796.61%
65038 56496     -371.2082   756       -42.0000     -376.5778 16884054  796.61%
65110 56516     -350.0730   368       -42.0000     -376.5778 16888980  796.61%
65158 56558     -235.2681   191       -42.0000     -376.5778 16892346  796.61%
65285 56665     -371.7312   780       -42.0000     -376.5778 16902786  796.61%
65319 56612     -366.8891  1013       -42.0000     -376.5778 16899193  796.61%
65328 56515     -369.2649   813       -42.0000     -376.5778 16898243  796.61%
65349 56619     -365.9130   961       -42.0000     -376.5778 16903443  796.61%
```

```
65377 56656     -374.9636   869      -42.0000     -376.5778 16903553  796.61%
65461 56566     -354.8815   435      -42.0000     -376.5778 16906832  796.61%
Elapsed time = 51.75 sec. (45094.74 ticks, tree = 2537.59 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
65538 56652     -352.6881   414      -42.0000     -376.5778 16912258  796.61%
65579 56663     -373.6537   807      -42.0000     -376.5778 16911756  796.61%
65603 56591     -375.1709   881      -42.0000     -376.5778 16912590  796.61%
65614 56685     -368.6663   587      -42.0000     -376.5778 16926075  796.61%
65654 56606     -326.8965   270      -42.0000     -376.5778 16919118  796.61%
65840 56689     -344.0531   352      -42.0000     -376.5778 16932035  796.61%
65863 56702     -353.1667   420      -42.0000     -376.5778 16935329  796.61%
65889 56719     -319.7314   372      -42.0000     -376.5778 16938567  796.61%
65911 56725     -322.5031   341      -42.0000     -376.5778 16941732  796.61%
65958 56694     -373.2894  1005      -42.0000     -376.5778 16931254  796.61%
Elapsed time = 62.90 sec. (55166.59 ticks, tree = 2544.63 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
65997 56768     -253.7349   280      -42.0000     -376.5778 16947850  796.61%
66033 56799     -200.2774   224      -42.0000     -376.5778 16951162  796.61%
66088 56579     -363.1327   912      -42.0000     -376.5778 16939742  796.61%
66104 56529     -366.7705   832      -42.0000     -376.5778 16919965  796.61%
66121 56540     -363.5003   629      -42.0000     -376.5778 16923506  796.61%
66256 56603     -333.1568   482      -42.0000     -376.5778 16927307  796.61%
66353 56781     -358.3175   407      -42.0000     -376.5778 16950761  796.61%
66420 56807     -333.2784   378      -42.0000     -376.5778 16954452  796.61%
66540 56939     -273.2919   280      -42.0000     -376.5778 16973671  796.61%
66663 56741     -346.7942   445      -42.0000     -376.5778 16960552  796.61%
Elapsed time = 74.45 sec. (65498.15 ticks, tree = 2558.25 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
66746 56738     -367.2268   477      -42.0000     -376.5778 16960134  796.61%
67127 56776     -342.2970   517      -42.0000     -376.5778 16968251  796.61%
67238 56999     -371.4690   752      -42.0000     -376.5778 16983874  796.61%
67266 57021     -333.9642   341      -42.0000     -376.5778 16987177  796.61%
67424 56898      -76.4479   160      -42.0000     -376.5778 16978530  796.61%
67530 57053     -373.1439   621      -42.0000     -376.5778 16993918  796.61%
67784 57039      -91.9323    75      -42.0000     -376.5778 16976965  796.61%
67923 57209     -374.6908   824      -42.0000     -376.5778 17000708  796.61%
67941 56855     -372.2216   428      -42.0000     -376.5778 16977830  796.61%
68103 56928     -331.4462   469      -42.0000     -376.5778 16990292  796.61%
Elapsed time = 85.79 sec. (75199.50 ticks, tree = 2566.21 MB, solutions = 8)
```

```
Nodefile size = 505.19 MB (457.73 MB after compression)
68294 56955     -247.9800   326      -42.0000     -376.5778 16984262  796.61%
68361 56926    infeasible            -42.0000     -376.5778 16995251  796.61%
68454 56941     -342.9196   259      -42.0000     -376.5778 16998376  796.61%
68580 56992     -249.5999   176      -42.0000     -376.5778 17002343  796.61%
68785 57111     -334.3761   321      -42.0000     -376.5778 16998461  796.61%
68946 56636     -370.2219  1051      -42.0000     -376.5778 16959597  796.61%
68960 57248    infeasible            -42.0000     -376.5778 17004796  796.61%
69028 57254    infeasible            -42.0000     -376.5778 17007632  796.61%
69137 57046        cutoff            -42.0000     -376.5778 17011825  796.61%
69146 57258     -374.6623   732      -42.0000     -376.5778 17013586  796.61%
Elapsed time = 96.76 sec. (84893.06 ticks, tree = 2553.89 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
69174 57079     -374.6247   714      -42.0000     -376.5778 17010021  796.61%
69379 57535     -154.2234    96      -42.0000     -376.5778 17040415  796.61%
69542 57048     -351.2630   495      -42.0000     -376.5778 17024459  796.61%
69611 57092     -249.8471   236      -42.0000     -376.5778 17027482  796.61%
69791 57123     -266.5293   180      -42.0000     -376.5778 17021100  796.61%
69896 57588    infeasible            -42.0000     -376.5778 17051599  796.61%
69900 57201     -372.7224   744      -42.0000     -376.5778 17026463  796.61%
69921 57253     -355.6185   324      -42.0000     -376.5778 17037474  796.61%
70000 57290     -294.2659   218      -42.0000     -376.5778 17038577  796.61%
70742 57498     -268.3576   172      -42.0000     -376.5778 17052046  796.61%
Elapsed time = 111.68 sec. (97530.70 ticks, tree = 2556.97 MB, solutions = 9)
Nodefile size = 505.19 MB (457.73 MB after compression)
71350 57728     -348.3798   248      -42.0000     -376.5778 17063553  796.61%
71743 57460     -373.4932   966      -42.0000     -376.5778 17049682  796.61%
71755 57653     -370.4464   636      -42.0000     -376.5778 17078692  796.61%
72187 57551     -215.6947   184      -42.0000     -376.5778 17066389  796.61%
72276 57850     -367.7073   661      -42.0000     -376.5778 17096223  796.61%
72618 57937     -157.8367   118      -42.0000     -376.5778 17107344  796.61%
73589 58103     -366.4535   645      -42.0000     -376.5778 17117318  796.61%
74114 58372     -220.1499   157      -42.0000     -376.5778 17127622  796.61%
74271 57688     -366.0440  1022      -42.0000     -376.5778 17107476  796.61%
74330 58468     -278.5357   406      -42.0000     -376.5778 17158803  796.61%
Elapsed time = 151.49 sec. (136817.80 ticks, tree = 2572.25 MB, solutions = 9)
Nodefile size = 505.19 MB (457.73 MB after compression)
74466 57137     -373.4744   786      -42.0000     -376.5778 17075738  796.61%
74579 57229     -125.4892   163      -42.0000     -376.5778 17083210  796.61%
```

```
74997 58823     -124.1569    77       -42.0000     -376.5778 17191261  796.61%
75138 57699     -351.9220   642       -42.0000     -376.5778 17150191  796.61%
75183 57727     -312.4915   310       -42.0000     -376.5778 17159655  796.61%
75598 57528        cutoff             -42.0000     -376.5778 17113472  796.61%
75757 57645     -372.7641   917       -42.0000     -376.5778 17123059  796.61%
75781 57652     -363.8514   654       -42.0000     -376.5778 17133198  796.61%
75914 57770     -368.0621   641       -42.0000     -376.5778 17141831  796.61%
76307 57888     -367.1160   710       -42.0000     -376.5778 17151066  796.61%
Elapsed time = 182.24 sec. (176632.97 ticks, tree = 2640.89 MB, solutions = 10)
Nodefile size = 505.19 MB (457.73 MB after compression)
76625 58372     -276.7328   275       -42.0000     -376.5778 17215778  796.61%
76896 58881     -363.3072   789       -42.0000     -376.5778 17266359  796.61%
77088 58341     -205.9310   178       -42.0000     -376.5778 17178206  796.61%
77452 58913     -289.3936   190       -42.0000     -376.5778 17282930  796.61%
77896 58805      -59.1187    71       -42.0000     -376.5778 17249555  796.61%
78198 58777     -104.5215   100       -42.0000     -376.5778 17202653  796.61%
78213 58926     -368.4008   652       -42.0000     -376.5778 17267554  796.61%
78401 58786     -372.5803  1028       -42.0000     -376.5778 17218675  796.61%
78547 59186     -304.1862   222       -42.0000     -376.5778 17287687  796.61%
78819 59304     -355.0582   246       -42.0000     -376.5778 17297787  796.61%
Elapsed time = 213.20 sec. (216193.23 ticks, tree = 2715.45 MB, solutions = 11)
Nodefile size = 505.19 MB (457.73 MB after compression)
* 78861+59332                           -43.0000     -376.5778           775.76%
78863 58919     -372.1730   923       -43.0000     -376.5778 17245546  775.76%
78865 58921     -362.0419   695       -43.0000     -376.5778 17262028  775.76%
78908 58961     -287.4919   224       -43.0000     -376.5778 17274297  775.76%
79046 59079     -351.1997   373       -43.0000     -376.5778 17285981  775.76%
79251 59269     -136.6352    93       -43.0000     -376.5778 17296280  775.76%
79485 59473     -331.8259   277       -43.0000     -376.5778 17304844  775.76%
79610 59575     -368.4471   613       -43.0000     -376.5778 17311192  775.76%
79779 59736     -235.4136   155       -43.0000     -376.5778 17320410  775.76%
79874 59817    infeasible             -43.0000     -376.5778 17331372  775.76%
79976 59913     -352.6447   359       -43.0000     -376.5778 17343498  775.76%
Elapsed time = 240.73 sec. (260469.65 ticks, tree = 2807.01 MB, solutions = 12)
Nodefile size = 505.19 MB (457.73 MB after compression)
80225 60135     -351.0370   334       -43.0000     -376.5778 17359520  775.76%
80482 60367     -372.6844  1128       -43.0000     -376.5778 17379949  775.76%
80486 60371     -370.6348   854       -43.0000     -376.5778 17391940  775.76%
80489 60374     -366.6817   652       -43.0000     -376.5778 17402505  775.76%
```

```
80618 60496     -366.6781   671      -43.0000     -376.5778 17414997  775.76%
80896 60756         cutoff           -43.0000     -376.5778 17426348  775.76%
81024 60865     -368.8018   769      -43.0000     -376.5778 17439191  775.76%
81161 60978    infeasible            -43.0000     -376.5778 17452029  775.76%
81372 61172     -368.2417   708      -43.0000     -376.5778 17463161  775.76%

GUB cover cuts applied:  916
Clique cuts applied:  53
Cover cuts applied:  3875
Implied bound cuts applied:  59
Flow cuts applied:  100
Mixed integer rounding cuts applied:  1398
Zero-half cuts applied:  121
Lift and project cuts applied:  9
Gomory fractional cuts applied:  198

Root node processing (before b&c):
Real time             =    0.00 sec. (0.97 ticks)
Parallel b&c, 8 threads:
Real time             =  278.62 sec. (311816.15 ticks)
Sync time (average)   =   11.93 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  278.62 sec. (311817.12 ticks)

------------------------------
Iteration 8
Bounds on # of cuts = 8 with [3 3 2]
Error = 57 (out of 100 instances)
Accuracy = 43
Solving time = 4.643691231 min (minutes)
Accumulated time = 23.299151648 min (minutes)

Solution status code = 104
LB on error =  -276.380316895
Relative objective gap = 7.753030625

Selected variables:
PEMLR (Categorical)
```

```
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                       3
CPXPARAM_MIP_Limits_Solutions                    1
CPXPARAM_TimeLimit                               85002.050901123046
CPXPARAM_MIP_Limits_TreeMemory                   204800

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

81435 71926     -369.0867   475      -43.0000     -376.3803 19472128  775.30%
Elapsed time = 3.10 sec. (2384.36 ticks, tree = 3375.96 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
81438 71929     -351.7855   242      -43.0000     -376.3803 19472768  775.30%
81471 71961     -270.8111   173      -43.0000     -376.3803 19473216  775.30%
81515 72001     -157.5837    98      -43.0000     -376.3803 19473641  775.30%
81563 71926     -374.3382   753      -43.0000     -376.3803 19473609  775.30%
81564 71928     -372.4402   715      -43.0000     -376.3803 19481748  775.30%
81567 71930     -371.4346   663      -43.0000     -376.3803 19482880  775.30%
81571 71933     -371.2108   644      -43.0000     -376.3803 19483675  775.30%
81572 71934     -370.7107   636      -43.0000     -376.3803 19484433  775.30%
81576 71931     -360.4175   763      -43.0000     -376.3803 19502020  775.30%
81661 72012     -144.5408   107      -43.0000     -376.3803 19488685  775.30%
Elapsed time = 9.37 sec. (7373.23 ticks, tree = 3370.21 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
81706 72044     -358.3163   625      -43.0000     -376.3803 19488229  775.30%
81757 72071     -303.3940   260      -43.0000     -376.3803 19492258  775.30%
82046 72027     -154.9862   247      -43.0000     -376.3803 19515571  775.30%
82190 72089     -266.6773   179      -43.0000     -376.3803 19502642  775.30%
82339 72085     -249.3634   162      -43.0000     -376.3803 19503964  775.30%
82548 71934     -359.2701   768      -43.0000     -376.3803 19543860  775.30%
82551 71937     -357.5116   530      -43.0000     -376.3803 19547438  775.30%
82574 71952     -339.6193   324      -43.0000     -376.3803 19550709  775.30%
82657 72026     -155.4003   164      -43.0000     -376.3803 19552766  775.30%
82707 72064     -355.4909   247      -43.0000     -376.3803 19555144  775.30%
Elapsed time = 23.10 sec. (18322.56 ticks, tree = 3345.19 MB, solutions = 13)
```

```
Nodefile size = 1328.84 MB (1208.58 MB after compression)
82804 72154     -136.7153    96      -43.0000     -376.3527 19557777  775.24%
82850 72307     -360.9410   741      -43.0000     -376.3527 19521065  775.24%
82855 72311     -342.6034   249      -43.0000     -376.1368 19523927  774.74%
82983 71936     -362.8146   626      -43.0000     -376.1368 19553992  774.74%
82985 72161     -371.0562   970      -43.0000     -376.1368 19520957  774.74%
82987 72193     -374.9001   951      -43.0000     -376.1368 19562191  774.74%
82993 71941     -358.9686   430      -43.0000     -376.1368 19567870  774.74%
82999 71946     -348.8783   255      -43.0000     -376.1368 19572436  774.74%
83050 71987     -258.2577   225      -43.0000     -376.1368 19574685  774.74%
83115 72047     -106.9395   149      -43.0000     -376.1368 19575766  774.74%
Elapsed time = 35.85 sec. (28977.15 ticks, tree = 3351.66 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
83146 72066    infeasible            -43.0000     -376.1368 19578155  774.74%
83150 72197     -355.5337   338      -43.0000     -376.1368 19576926  774.74%
83255 72221     -222.3896   129      -43.0000     -376.1368 19540293  774.74%
83429 72318        cutoff            -43.0000     -376.1368 19579829  774.74%
83434 72191     -359.3736   818      -43.0000     -376.1368 19542416  774.74%
83449 72287     -371.6337   619      -43.0000     -376.1368 19550427  774.74%
83487 72317     -265.8980   174      -43.0000     -376.1368 19553782  774.74%
83744 72447     -333.6008   253      -43.0000     -376.1368 19553268  774.74%
83839 72511     -194.0038   122      -43.0000     -376.1368 19554512  774.74%
83950 72252     -192.8584   143      -43.0000     -376.1368 19555244  774.74%
Elapsed time = 48.25 sec. (39354.87 ticks, tree = 3364.70 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
84017 72081     -354.4707   699      -43.0000     -376.1368 19578452  774.74%
84023 72069     -366.0459   957      -43.0000     -376.1368 19597048  774.74%
84036 71956     -348.2522   252      -43.0000     -376.1368 19588460  774.74%
84184 72414     -333.2872   216      -43.0000     -376.1368 19572926  774.74%
84316 72094     -351.1716   513      -43.0000     -376.1368 19591693  774.74%
84492 72137     -253.3089   162      -43.0000     -376.1368 19595305  774.74%
84589 72520     -372.8630   619      -43.0000     -376.1368 19581721  774.74%
84631 72559     -273.3236   176      -43.0000     -376.1368 19584387  774.74%
84755 72337     -342.0960   228      -43.0000     -376.1368 19606229  774.74%
84999 72657     -350.7128   344      -43.0000     -376.1368 19589927  774.74%
Elapsed time = 59.71 sec. (49483.74 ticks, tree = 3372.85 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
85177 72284     -200.4956   128      -43.0000     -376.1368 19608089  774.74%
85252 72564     -366.6790   841      -43.0000     -376.1368 19577339  774.74%
```

```
85269 72536    infeasible             -43.0000     -376.1368 19591276  774.74%
85318 72802     -272.0554   179       -43.0000     -376.1368 19598160  774.74%
85458 72106     -271.7240   204       -43.0000     -376.1368 19630436  774.74%
85583 72343     -369.7473   635       -43.0000     -376.1368 19620884  774.74%
85753 72537     -368.2100   867       -43.0000     -376.1368 19598411  774.74%
85869 72101     -319.9908   214       -43.0000     -376.1368 19628379  774.74%
86144 72573     -271.7490   196       -43.0000     -376.1368 19604341  774.74%
86291 72116     -306.6315   350       -43.0000     -376.1368 19628397  774.74%
Elapsed time = 72.00 sec. (59610.39 ticks, tree = 3339.28 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
86447 72541     -125.2543    65       -43.0000     -376.1368 19631988  774.74%
86788 72227      -46.0606   174       -43.0000     -376.1368 19635812  774.74%
86904 72855      -90.1545    54       -43.0000     -376.1368 19614400  774.74%
86987 72371     -183.6352   116       -43.0000     -376.1368 19641703  774.74%
87059 72230     -371.5048   694       -43.0000     -376.1368 19641837  774.74%
87140 72762     -210.2776   139       -43.0000     -376.1368 19616474  774.74%
87328 72220     -366.7426   657       -43.0000     -376.1368 19654622  774.74%
87338 72227     -342.5130   261       -43.0000     -376.1368 19658216  774.74%
87497 73022     -331.2281   315       -43.0000     -376.1368 19630982  774.74%
87569 73080     -184.5925   181       -43.0000     -376.1368 19631567  774.74%
Elapsed time = 83.56 sec. (69415.07 ticks, tree = 3374.71 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
87722 72426     -196.0292   354       -43.0000     -376.1368 19658817  774.74%
87813 72470     -313.7015   224       -43.0000     -376.1368 19657117  774.74%
88010 73139     -332.3763   232       -43.0000     -376.1368 19638071  774.74%
88193 72344     -369.2216   688       -43.0000     -376.1368 19671787  774.74%
88226 72439     -344.1819   306       -43.0000     -376.1368 19663453  774.74%
88382 73331     -108.0697    65       -43.0000     -376.1368 19645596  774.74%
88585 72524     -154.1781   103       -43.0000     -376.1368 19666440  774.74%
88643 72580     -341.4974   385       -43.0000     -376.1368 19679295  774.74%
88686 72613     -276.5086   221       -43.0000     -376.1368 19683720  774.74%
88853 73404     -204.9500   146       -43.0000     -376.1368 19657466  774.74%
Elapsed time = 96.42 sec. (79164.76 ticks, tree = 3376.03 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
88930 72572     -371.0431   728       -43.0000     -376.1368 19675302  774.74%
88947 72490     -365.6207   494       -43.0000     -376.1368 19682400  774.74%
89059 72630     -210.4036   137       -43.0000     -376.1368 19680104  774.74%
89353 73556     -174.7126   116       -43.0000     -376.1368 19669157  774.74%
89437 72881     -348.1156   280       -43.0000     -376.1368 19641906  774.74%
```

```
89803 72768     -138.0596    89      -43.0000     -376.1368 19686828  774.74%
90099 73621     -369.2874   668      -43.0000     -376.1368 19676578  774.74%
90187 72870     -145.8195    96      -43.0000     -376.1368 19692884  774.74%
90391 72907     -350.2219   270      -43.0000     -376.1368 19696002  774.74%
90568 72953     -260.3118   162      -43.0000     -376.1368 19699570  774.74%
Elapsed time = 107.23 sec. (88918.59 ticks, tree = 3355.42 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
90747 73000     -232.2603   144      -43.0000     -376.1368 19670487  774.74%
90865 73685     -212.0829   144      -43.0000     -376.1368 19685798  774.74%
91021 73711     -147.6431   128      -43.0000     -376.1368 19686698  774.74%
91106 73041     -279.0274   184      -43.0000     -376.1368 19662197  774.74%
91217 72694     -367.0982   639      -43.0000     -376.1368 19714979  774.74%
91226 72696     -364.1187   634      -43.0000     -376.1368 19718381  774.74%
91279 73087     -334.1832   285      -43.0000     -376.1368 19684478  774.74%
91581 72886     -239.2958   177      -43.0000     -376.1368 19731529  774.74%
91880 72773     -172.1287   147      -43.0000     -376.1368 19724728  774.74%
92103 72979     -318.1041   204      -43.0000     -376.1368 19741671  774.74%
Elapsed time = 122.50 sec. (101620.07 ticks, tree = 3349.38 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
92488 73193     -370.3096   645      -43.0000     -376.1368 19705612  774.74%
92693 73253     -263.1795   257      -43.0000     -376.1368 19716357  774.74%
93074 72883     -356.9105   851      -43.0000     -376.1368 19744324  774.74%
93449 72909     -298.8729   213      -43.0000     -376.1368 19753841  774.74%
94224 73670     -245.3925   164      -43.0000     -376.1368 19727039  774.74%
95151 73027     -142.9352   102      -43.0000     -376.1368 19773585  774.74%
96004 73918     -234.3377   168      -43.0000     -376.1368 19744955  774.74%
96537 75077      -76.1794    41      -43.0000     -376.1368 19787753  774.74%
97188 73361     -339.1905   244      -43.0000     -376.1368 19803446  774.74%
97957 73408      -98.3815    50      -43.0000     -376.1368 19811535  774.74%
Elapsed time = 169.17 sec. (140231.77 ticks, tree = 3363.58 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
98359 73123     -368.1863   739      -43.0000     -376.1368 19803156  774.74%
99166 73425     -362.4546   512      -43.0000     -376.1368 19828990  774.74%
99573 74050     -348.9752   262      -43.0000     -376.1368 19832253  774.74%
*100206+75506                          -44.0000     -376.1368            754.86%
100260 74255     -187.1122   111      -44.0000     -376.1368 19841225  754.86%
100755 73923     -141.6525    76      -44.0000     -376.1368 19855053  754.86%
101360 74183     -254.1317   165      -44.0000     -376.1368 19869790  754.86%
101983 74396     -365.9683   679      -44.0000     -376.1368 19880718  754.86%
```

```
102256 73251     -358.7644   844      -44.0000     -376.1368 19850813  754.86%
102534 74551     -369.3515   969      -44.0000     -376.1368 19886540  754.86%
102636 74685     -201.0157   189      -44.0000     -376.1368 19906540  754.86%
Elapsed time = 213.97 sec. (178886.70 ticks, tree = 3369.28 MB, solutions = 14)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
103075 74690     -137.0039    86      -44.0000     -376.1368 19858793  754.86%
103324 74781     -259.5830   176      -44.0000     -376.1368 19870758  754.86%
103868 73707     -357.3355   710      -44.0000     -376.1368 19916863  754.86%
104488 74966     -156.8062   105      -44.0000     -376.1368 19935045  754.86%
104840 73993     -298.3118   195      -44.0000     -376.1368 19937028  754.86%
105230 74463     -370.2003   680      -44.0000     -376.1368 19945863  754.86%
106185 75111     -328.7164   230      -44.0000     -376.1368 19921098  754.86%
106948 74994      -64.9639    51      -44.0000     -376.1368 19976173  754.86%
107545 75108     -275.3044   179      -44.0000     -376.1368 19985828  754.86%
108190 74573     -122.1881    75      -44.0000     -376.1368 19949611  754.86%
Elapsed time = 255.53 sec. (217150.33 ticks, tree = 3470.33 MB, solutions = 15)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
108890 74604     -302.1580   203      -44.0000     -376.1368 19988782  754.86%
109683 74939      -72.1704    42      -44.0000     -376.1368 19996434  754.86%
110213 75844     -152.6764   113      -44.0000     -376.1368 20025497  754.86%
110687 74738     -372.4462   654      -44.0000     -376.1368 19979491  754.86%
111104 75218     -255.9594   181      -44.0000     -376.1368 20021953  754.86%
111226 75914     -280.6563   210      -44.0000     -376.1368 20052210  754.86%
111818 75067     -108.0074    75      -44.0000     -376.1368 20004989  754.86%
112086 74183     -175.7369   112      -44.0000     -376.1368 20000307  754.86%
112565 76266     -241.4723   169      -44.0000     -376.1368 20079748  754.86%
113030 76439     -164.3090   212      -44.0000     -376.1368 20090558  754.86%
Elapsed time = 300.62 sec. (255370.86 ticks, tree = 3493.07 MB, solutions = 16)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
113440 75423     -356.3437   390      -44.0000     -376.1368 20066747  754.86%
113846 75655     -329.7125   232      -44.0000     -376.1368 20074973  754.86%
114376 76956     -372.7014   765      -44.0000     -376.1368 20119752  754.86%
114992 75269     -357.7460   861      -44.0000     -376.1368 20084688  754.86%
115064 75899     -244.1868   170      -44.0000     -376.1368 20104973  754.86%
115422 75281     -356.3431   761      -44.0000     -376.1368 20099647  754.86%
115659 77257     -354.9574   229      -44.0000     -376.1368 20156509  754.86%
116481 77486     -350.4063   259      -44.0000     -376.1368 20166270  754.86%
117012 74851     -338.6518   338      -44.0000     -376.1368 20099673  754.86%
117672 76593      -73.3108    55      -44.0000     -376.1368 20139708  754.86%
```

```
Elapsed time = 340.22 sec. (294342.29 ticks, tree = 3590.75 MB, solutions = 16)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
118392 76837      -340.1003   223       -44.0000     -376.1368 20149430  754.86%
118661 76951      -338.5554   252       -44.0000     -376.1368 20159026  754.86%
119232 78202      -370.3891   879       -44.0000     -376.1368 20206881  754.86%
119504 78208      -365.8875   675       -44.0000     -376.1368 20215279  754.86%
120370 78339      -294.4108   228       -44.0000     -376.1368 20224887  754.86%
120736 77663      -371.1597   751       -44.0000     -376.1368 20197661  754.86%
121137 78468      -263.1958   171       -44.0000     -376.1368 20240044  754.86%
121380 76760      -361.0483   578       -44.0000     -376.1368 20206996  754.86%
121504 78546      -372.0299   951       -44.0000     -376.1368 20254287  754.86%
121709 77052      -189.2273   149       -44.0000     -376.1368 20224660  754.86%
Elapsed time = 369.68 sec. (333296.33 ticks, tree = 3591.38 MB, solutions = 17)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
121787 77894      -347.8439   314       -44.0000     -376.1368 20232409  754.86%
121944 78563      -362.8561   674       -44.0000     -376.1368 20281358  754.86%
122228 78030      -369.6159   952       -44.0000     -376.1368 20251103  754.86%
122239 78035      -365.2604   668       -44.0000     -376.1368 20260623  754.86%
122604 79033      -116.1095    76       -44.0000     -376.1368 20304884  754.86%
122641 77112      -360.7584   740       -44.0000     -376.1368 20264111  754.86%
122909 79061      -359.0364   761       -44.0000     -376.1368 20328240  754.86%
122912 79064      -345.4132   728       -44.0000     -376.1368 20339694  754.86%
123088 79214      -340.4910   331       -44.0000     -376.1368 20349332  754.86%
123335 79434      -366.9963   736       -44.0000     -376.1368 20359227  754.86%
Elapsed time = 386.93 sec. (378266.74 ticks, tree = 3689.23 MB, solutions = 18)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
123606 77360      -367.9078   813       -44.0000     -376.1368 20304015  754.86%
123789 77402      -270.6668   213       -44.0000     -376.1368 20313171  754.86%
124252 77565      -147.9091   111       -44.0000     -376.1368 20322273  754.86%
124710 80275      -339.1575   259       -44.0000     -376.1368 20399552  754.86%
125071 80455      -130.4602    96       -44.0000     -376.1368 20407189  754.86%
125120 80488      -364.5023   979       -44.0000     -376.1368 20414180  754.86%
125393 78074       -67.5268    51       -44.0000     -376.1368 20356949  754.86%
125548 78206       -61.4737    25       -44.0000     -376.1368 20365875  754.86%
125824 80617      -365.8242   646       -44.0000     -376.1368 20434361  754.86%
126311 80820      -149.0581   106       -44.0000     -376.1368 20445898  754.86%
Elapsed time = 402.92 sec. (417930.32 ticks, tree = 3750.55 MB, solutions = 18)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
126818 78688      -359.1233   621       -44.0000     -376.1368 20397046  754.86%
```

```
127130 78818     -361.6743   326      -44.0000     -376.1368 20405785  754.86%
127645 81464    infeasible            -44.0000     -376.1368 20480980  754.86%
127773 79050     -370.5096   967      -44.0000     -376.1368 20420424  754.86%
128047 79052     -369.8842   919      -44.0000     -376.1368 20426470  754.86%
128292 82017     -100.5857    62      -44.0000     -376.1368 20513017  754.86%
128338 82042     -364.7610   328      -44.0000     -376.1368 20523898  754.86%
128527 79071     -360.6063   650      -44.0000     -376.1368 20446426  754.86%
128837 82360     -201.0485   146      -44.0000     -376.1368 20543286  754.86%
129157 82638     -369.1021   836      -44.0000     -376.1368 20553236  754.86%
Elapsed time = 433.80 sec. (460667.96 ticks, tree = 3767.71 MB, solutions = 19)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
129298 82771      -49.6236    49      -44.0000     -376.1368 20560041  754.86%
129563 83000     -360.7373   441      -44.0000     -376.1368 20569164  754.86%
129908 83292     -150.2737   107      -44.0000     -376.1368 20580126  754.86%
130141 83494     -240.2222   141      -44.0000     -376.1368 20590944  754.86%
130362 83680     -370.2243   736      -44.0000     -376.1368 20601487  754.86%
130505 83814     -359.7878   388      -44.0000     -376.1368 20614667  754.86%
130871 84128     -128.4628    80      -44.0000     -376.1368 20623685  754.86%

GUB cover cuts applied:  1043
Clique cuts applied:  57
Cover cuts applied:  4277
Implied bound cuts applied:  68
Flow cuts applied:  118
Mixed integer rounding cuts applied:  1735
Zero-half cuts applied:  125
Lift and project cuts applied:  9
Gomory fractional cuts applied:  199

Root node processing (before b&c):
Real time             =    0.00 sec. (1.39 ticks)
Parallel b&c, 8 threads:
Real time             =  460.44 sec. (493387.72 ticks)
Sync time (average)   =    9.29 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  460.44 sec. (493389.11 ticks)

------------------------------
```

```
Iteration 9
Bounds on # of cuts = 8 with [3 3 2]
Error = 56 (out of 100 instances)
Accuracy = 44
Solving time = 7.674096716 min (minutes)
Accumulated time = 30.973248364 min (minutes)

Solution status code = 104
LB on error =  -275.942710447
Relative objective gap = 7.54415251

Selected variables:
PEMLR (Categorical)
SS_YN (Categorical)

Number of selected variables = 2 (0 continuous + 2 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                        3
CPXPARAM_MIP_Limits_Solutions                     1
CPXPARAM_TimeLimit                                84541.60509814453
CPXPARAM_MIP_Limits_TreeMemory                    204800

Nodes                                          Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

130908 115417    infeasible           -44.0000     -375.9427 24852547  754.42%
Elapsed time = 0.21 sec. (11.76 ticks, tree = 4875.97 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
130946 115453      -75.7118    39      -44.0000     -375.9427 24852830  754.42%
130960 115461    infeasible           -44.0000     -375.9427 24854245  754.42%
130961 115417    infeasible           -44.0000     -375.9427 24855273  754.42%
130962 115419     -375.5477   854      -44.0000     -375.9427 24854727  754.42%
130963 115462     -374.5850   952      -44.0000     -375.9427 24856324  754.42%
130964 115419     -374.8863   762      -44.0000     -375.9239 24859471  754.37%
130966 115420     -370.7308   599      -44.0000     -375.9239 24861461  754.37%
130970 115420     -365.1263   677      -44.0000     -375.9239 24865366  754.37%
130974 115425     -353.5129   272      -44.0000     -375.9239 24863328  754.37%
131072 115431     -318.7079   260      -44.0000     -375.9239 24868843  754.37%
```

```
Elapsed time = 6.88 sec. (4499.63 ticks, tree = 4853.98 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
131222 115489     -186.2469   144      -44.0000     -375.9239 24869233  754.37%
131419 115588     -227.5296   151      -44.0000     -375.9064 24867646  754.33%
131578 115473     -365.3839   660      -44.0000     -375.9064 24885085  754.33%
131721 115419     -364.6390   889      -44.0000     -375.9064 24870560  754.33%
131724 115420     -363.4877   908      -44.0000     -375.9064 24872570  754.33%
131728 115601     -368.4619   691      -44.0000     -375.9064 24886633  754.33%
131749 115614     -344.4963   237      -44.0000     -375.9064 24889538  754.33%
131877 115538     -365.3678   477      -44.0000     -375.9064 24884596  754.33%
131914 115567     -282.2076   191      -44.0000     -375.9064 24887643  754.33%
132035 115773     -357.5782   691      -44.0000     -375.9064 24887689  754.33%
Elapsed time = 20.65 sec. (15475.37 ticks, tree = 4891.62 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
132298 115478     -363.3619   938      -44.0000     -375.9064 24905374  754.33%
132305 115885     -365.9278   666      -44.0000     -375.9064 24893668  754.33%
132438 115476     -371.2272   830      -44.0000     -375.9064 24902926  754.33%
132450 115660     -367.9299   777      -44.0000     -375.6031 24899669  753.64%
132461 115721     -365.2211   688      -44.0000     -375.6031 24906865  753.64%
132632 115757     -133.2122    81      -44.0000     -375.6031 24904356  753.64%
132765 115485     -337.9961   301      -44.0000     -375.6031 24920324  753.64%
132903 115483     -354.2930   485      -44.0000     -375.6031 24918321  753.64%
132974 115524     -276.5625   264      -44.0000     -375.6031 24920543  753.64%
133138 116022     -319.0843   203      -44.0000     -375.6031 24912566  753.64%
Elapsed time = 33.13 sec. (25766.01 ticks, tree = 4914.84 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
133451 115867     -144.2583    99      -44.0000     -375.6031 24916493  753.64%
133606 116211      -45.0030    24      -44.0000     -375.6031 24916465  753.64%
133745 115906     -235.1235   148      -44.0000     -375.6031 24924857  753.64%
134004 115642     -254.9202   165      -44.0000     -375.6031 24933906  753.64%
134329 115597      -79.8389    61      -44.0000     -375.6031 24927955  753.64%
134423 116045     -141.1138   100      -44.0000     -375.6031 24933151  753.64%
134467 115718     -373.6129   866      -44.0000     -375.6031 24938524  753.64%
134536 115666     -199.6527   129      -44.0000     -375.6031 24932904  753.64%
134612 115721     -354.9792   377      -44.0000     -375.6031 24943712  753.64%
134717 116230     -335.6979   239      -44.0000     -375.6031 24937404  753.64%
Elapsed time = 44.97 sec. (35418.05 ticks, tree = 4934.31 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
135026 115538     -238.0279   154      -44.0000     -375.6031 24941038  753.64%
```

```
135204 115612     -369.4843   771      -44.0000     -375.6031 24941848  753.64%
135514 116263     -248.8541   173      -44.0000     -375.6031 24945872  753.64%
135735 115696     -158.7882   110      -44.0000     -375.6031 24946026  753.64%
135885 116414     -164.6318   107      -44.0000     -375.6031 24949736  753.64%
136157 115950      -98.4789    83      -44.0000     -375.6031 24954128  753.64%
136177 116049     -371.4216   844      -44.0000     -375.6031 24942096  753.64%
136184 115729     -359.2447   647      -44.0000     -375.6031 24956224  753.64%
136316 116080      -98.6373    67      -44.0000     -375.6031 24961109  753.64%
136393 116100     -349.1181   249      -44.0000     -375.6031 24963534  753.64%
Elapsed time = 57.63 sec. (45651.53 ticks, tree = 4905.68 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
136849 115888     -253.3435   164      -44.0000     -375.6031 24959565  753.64%
137050 116213     -367.0710   403      -44.0000     -375.6031 24967308  753.64%
137303 115892     -370.9447   739      -44.0000     -375.6031 24969401  753.64%
137389 116655     -171.9714   119      -44.0000     -375.6031 24969048  753.64%
137495 115924     -298.0111   212      -44.0000     -375.6031 24973699  753.64%
137631 115998     -263.0363   183      -44.0000     -375.6031 24969968  753.64%
137795 116758     -248.3035   154      -44.0000     -375.6031 24976581  753.64%
137891 116269     -369.5074   798      -44.0000     -375.6031 24966502  753.64%
137901 115848     -360.4711   938      -44.0000     -375.5768 24990340  753.58%
137906 116274     -365.3659   725      -44.0000     -375.5768 24971064  753.58%
Elapsed time = 70.87 sec. (56061.54 ticks, tree = 4932.76 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
137960 116487     -316.4243   288      -44.0000     -375.5768 24985812  753.58%
138142 116067     -228.0601   154      -44.0000     -375.5768 24985266  753.58%
138227 115731     -362.3989   865      -44.0000     -375.5768 24979413  753.58%
138244 116283     -344.5858   239      -44.0000     -375.5768 24983061  753.58%
138307 115736     -359.8629   779      -44.0000     -375.5768 24983469  753.58%
138489 115938     -175.9894   129      -44.0000     -375.5768 25004586  753.58%
138590 115775     -255.4406   180      -44.0000     -375.5768 24988921  753.58%
138814 116345     -359.1724   760      -44.0000     -375.5768 24995243  753.58%
139074 115974     -105.0916    65      -44.0000     -375.5768 24992675  753.58%
139113 116128     -374.1367   970      -44.0000     -375.5768 24991767  753.58%
Elapsed time = 82.98 sec. (65890.40 ticks, tree = 4914.26 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
139288 116450        cutoff            -44.0000     -375.5768 25002072  753.58%
139503 116586     -365.1134   478      -44.0000     -375.5768 25000336  753.58%
139743 116674     -294.4688   225      -44.0000     -375.5768 24997586  753.58%
139909 116748     -108.7938    89      -44.0000     -375.5768 24997959  753.58%
```

```
139971 116095    -335.3009   237      -44.0000     -375.5768 25004249  753.58%
140220 116203     -69.1186    46      -44.0000     -375.5768 25004973  753.58%
140240 116121    -362.5128   582      -44.0000     -375.5768 25007014  753.58%
140401 116148    -303.0626   212      -44.0000     -375.5768 25009101  753.58%
140517 116574    -348.2827   284      -44.0000     -375.5768 25019146  753.58%
140699 116276    -258.9445   196      -44.0000     -375.5768 25012673  753.58%
Elapsed time = 94.85 sec. (75581.51 ticks, tree = 4917.26 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
140877 116078    -121.0623    82      -44.0000     -375.5768 25036048  753.58%
140925 116350    -343.0377   230      -44.0000     -375.5768 25017733  753.58%
141100 116151    -232.2341   177      -44.0000     -375.5768 25039954  753.58%
141253 117269    -234.1615   167      -44.0000     -375.5768 25034933  753.58%
141416 116174    -281.4930   181      -44.0000     -375.5768 25019843  753.58%
141745 116720    -364.4253   455      -44.0000     -375.5768 25034074  753.58%
141861 116802    -175.3061   289      -44.0000     -375.5768 25036560  753.58%
142147 116886    -280.5945   190      -44.0000     -375.5768 25034867  753.58%
142406 117437    -150.9468   103      -44.0000     -375.5768 25044378  753.58%
142489 116212    -373.2448   888      -44.0000     -375.5768 25048786  753.58%
Elapsed time = 106.60 sec. (85221.60 ticks, tree = 4909.58 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
142508 117488    -336.2286   214      -44.0000     -375.5768 25048940  753.58%
142640 116225    -363.3862   631      -44.0000     -375.5768 25033233  753.58%
142775 116458    -157.0598   131      -44.0000     -375.5768 25036898  753.58%
142949 117590    -353.3226   361      -44.0000     -375.5768 25056638  753.58%
143076 116219    -361.4628   313      -44.0000     -375.5768 25060174  753.58%
143254 118022    -345.2241   249      -44.0000     -375.5297 25176661  753.48%
143691 116631     -45.6814    55      -44.0000     -375.5297 25047642  753.48%
143831 116896    -258.8147   156      -44.0000     -375.5297 25056621  753.48%
143932 117151    -370.4339   702      -44.0000     -375.5297 25050563  753.48%
144503 116351    -361.2385   431      -44.0000     -375.5297 25058610  753.48%
Elapsed time = 124.41 sec. (98029.26 ticks, tree = 4935.34 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
145598 118282     -84.7192    45      -44.0000     -375.5297 25200709  753.48%
146286 116663    -146.1327   110      -44.0000     -375.5297 25086583  753.48%
146983 118364    -196.2860   147      -44.0000     -375.5297 25217258  753.48%
147695 116842    -288.8602   173      -44.0000     -375.5297 25106005  753.48%
148179 118682    -364.6394   681      -44.0000     -375.5297 25235746  753.48%
148895 118808     -45.9513    35      -44.0000     -375.5297 25239563  753.48%
149564 117128    -102.2161   125      -44.0000     -375.5297 25113787  753.48%
```

```
150155 117500     -250.4974   176      -44.0000     -375.5297 25113826  753.48%
151053 117401     -133.1193    72      -44.0000     -375.5297 25149498  753.48%
152268 117266      -74.6968    45      -44.0000     -375.5297 25133951  753.48%
Elapsed time = 171.10 sec. (136215.45 ticks, tree = 5020.68 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
153265 117421     -131.6317    86      -44.0000     -375.5297 25148312  753.48%
153651 123366     -204.8835   135      -44.0000     -375.5297 25710075  753.48%
154291 127032     -273.1402   193      -44.0000     -375.4562 26185133  753.31%
154685 132699     -230.5562   138      -44.0000     -375.4562 26809062  753.31%
155410 135455      -86.7902    48      -44.0000     -375.0224 27113648  752.32%
156010 135713     -353.6035   369      -44.0000     -374.9424 27159569  752.14%
156428 136562     -373.1474   752      -44.0000     -374.9424 27240959  752.14%
156856 136991     -207.2019   119      -44.0000     -374.9424 27278840  752.14%
157325 137622     -282.8151   202      -44.0000     -374.6467 27376398  751.47%
157554 137746     -361.1068   365      -44.0000     -374.6467 27400626  751.47%
Elapsed time = 229.01 sec. (174835.59 ticks, tree = 6750.00 MB, solutions = 20)
Nodefile size = 4694.67 MB (4271.79 MB after compression)
158142 137958     -121.8675    82      -44.0000     -374.6467 27423219  751.47%
158452 138468      -76.5513    58      -44.0000     -374.3973 27479789  750.90%
158893 138456     -347.6235   270      -44.0000     -374.3973 27513832  750.90%
159308 139453      -83.8846    50      -44.0000     -374.3973 27639581  750.90%
159480 139089     -351.9897   348      -44.0000     -374.2840 27601366  750.65%
159932 140136     -288.8156   190      -44.0000     -374.2840 27773711  750.65%
160342 139970     -351.9906   293      -44.0000     -374.2840 27751169  750.65%
161057 140601     -366.0149   640      -44.0000     -374.2840 27867684  750.65%
162160 140791     -223.6580   127      -44.0000     -374.2101 27879510  750.48%
163097 142224     -222.4034   148      -44.0000     -374.1965 28026597  750.45%
Elapsed time = 278.81 sec. (213139.08 ticks, tree = 6770.20 MB, solutions = 20)
Nodefile size = 4714.67 MB (4281.11 MB after compression)
163912 142512    infeasible            -44.0000     -374.1965 28049351  750.45%
164581 143728      -93.8205    59      -44.0000     -374.0908 28152876  750.21%
165350 144119      -79.5072    47      -44.0000     -374.0698 28225664  750.16%
165945 144892     -229.1467   130      -44.0000     -374.0698 28296508  750.16%
166536 145100     -279.1562   190      -44.0000     -374.0698 28313847  750.16%
167263 145224     -248.0966   153      -44.0000     -374.0500 28324091  750.11%
167930 146403     -350.6970   275      -44.0000     -373.9883 28442310  749.97%
168968 146615     -100.5712    70      -44.0000     -373.9312 28450581  749.84%
169395 147938     -355.1343   366      -44.0000     -373.9312 28581082  749.84%
170326 148098     -257.4100   169      -44.0000     -373.9312 28588582  749.84%
```

```
Elapsed time = 328.74 sec. (251329.20 ticks, tree = 6859.09 MB, solutions = 20)
Nodefile size = 4790.43 MB (4339.89 MB after compression)
170842 148288     -349.1396   362       -44.0000     -373.9124 28607750  749.80%
171150 149503     -320.2788   218       -44.0000     -373.9124 28727565  749.80%
171832 149966     -350.6827   359       -44.0000     -373.8929 28794113  749.76%
172192 150174     -170.2027   122       -44.0000     -373.8929 28843720  749.76%
172580 149983     -359.4415   786       -44.0000     -373.8929 28820435  749.76%
172880 151136     -335.9286   284       -44.0000     -373.8929 28944854  749.76%
173494 151420     -241.2605   162       -44.0000     -373.8929 28978189  749.76%
173961 151599      -79.5849    38       -44.0000     -373.8929 29002456  749.76%
174586 152338     -361.9703   801       -44.0000     -373.8929 29088367  749.76%
175313 152491     -326.2307   218       -44.0000     -373.8929 29085315  749.76%
Elapsed time = 380.88 sec. (289676.74 ticks, tree = 7073.81 MB, solutions = 20)
Nodefile size = 4990.52 MB (4516.97 MB after compression)
176015 152689     -289.1985   182       -44.0000     -373.8929 29144336  749.76%
176855 154160      -77.4398    37       -44.0000     -373.8929 29266758  749.76%
177448 154194     -290.7869   193       -44.0000     -373.8929 29274335  749.76%
177800 155086     -352.6978   552       -44.0000     -373.8929 29417626  749.76%
178144 155126     -277.9166   175       -44.0000     -373.8929 29427343  749.76%
178488 155853     -325.1799   217       -44.0000     -373.6771 29539764  749.27%
178978 155690     -227.7448   269       -44.0000     -373.6771 29534376  749.27%
179678 156294     -172.5863    99       -44.0000     -373.6130 29606670  749.12%
180144 157102     -355.1944   657       -44.0000     -373.6099 29747844  749.11%
180869 157097     -338.7220   212       -44.0000     -373.5628 29743077  749.01%
Elapsed time = 433.30 sec. (328264.55 ticks, tree = 7285.22 MB, solutions = 20)
Nodefile size = 5230.30 MB (4731.06 MB after compression)
181719 157876     -303.7777   268       -44.0000     -373.5628 29865351  749.01%
182794 159272     -237.1395   147       -44.0000     -373.5628 29984307  749.01%
183348 159346     -351.1395   663       -44.0000     -373.5628 30006348  749.01%
184056 160314     -367.6314   687       -44.0000     -373.4833 30086392  748.83%
184762 160989      -99.2792    65       -44.0000     -373.4409 30149317  748.73%
185495 161553     -357.1583   641       -44.0000     -373.4409 30227053  748.73%
186459 162127     -156.6030    90       -44.0000     -373.4409 30284992  748.73%
187261 161936      -61.7549    32       -44.0000     -373.3481 30259262  748.52%
188114 162740      -73.0164    36       -44.0000     -373.3443 30325642  748.51%
189070 163956     -152.9141    96       -44.0000     -373.3443 30438865  748.51%
Elapsed time = 486.25 sec. (367163.04 ticks, tree = 7512.82 MB, solutions = 20)
Nodefile size = 5447.40 MB (4922.11 MB after compression)
189644 164386     -367.8376   887       -44.0000     -373.3443 30477271  748.51%
```

```
190685 164981     -87.2124    61      -44.0000     -373.3443 30514247  748.51%
191184 166418    -333.6920   221      -44.0000     -373.3443 30646990  748.51%
192458 166950    -208.3170   120      -44.0000     -373.3443 30699405  748.51%
193547 167529    -198.3154   118      -44.0000     -373.3443 30739547  748.51%
194774 168011    -168.6088   199      -44.0000     -373.2787 30794964  748.36%
195925 168908    -142.5090   148      -44.0000     -373.2427 30835364  748.28%
196620 171308    -224.7571   158      -44.0000     -373.2408 30997697  748.27%
197264 171376    -371.6623   716      -44.0000     -373.2408 31005841  748.27%
198034 171635    -208.1538   134      -44.0000     -373.2055 31055553  748.19%
Elapsed time = 539.69 sec. (405452.81 ticks, tree = 7961.62 MB, solutions = 20)
Nodefile size = 5907.38 MB (5338.30 MB after compression)
198412 172029    -289.5103   235      -44.0000     -373.2055 31095374  748.19%
198962 172723    -143.3916    95      -44.0000     -373.2055 31160733  748.19%
199414 172871    -308.1767   199      -44.0000     -373.2055 31188479  748.19%
200445 174277     -67.7922    28      -44.0000     -373.1191 31301581  748.00%
201225 174685    -365.1012   671      -44.0000     -373.1191 31351164  748.00%
201850 175086    -310.6747   205      -44.0000     -373.1191 31384774  748.00%
202420 176028    -299.8808   228      -44.0000     -373.1191 31500120  748.00%
202989 176150    -356.5293   345      -44.0000     -373.1191 31508469  748.00%
203966 177277    -349.3249   252      -44.0000     -373.1191 31616486  748.00%
204804 177320    -351.0572   257      -44.0000     -373.0455 31638301  747.83%
Elapsed time = 590.71 sec. (444013.14 ticks, tree = 8114.88 MB, solutions = 20)
Nodefile size = 6058.27 MB (5468.92 MB after compression)
205628 178179    -111.3682    81      -44.0000     -373.0143 31717251  747.76%
206144 178259    -197.6408   123      -44.0000     -373.0143 31727454  747.76%
206619 178812    -178.9469   189      -44.0000     -372.9949 31789311  747.72%
207249 179762    -363.1710   818      -44.0000     -372.9899 31871857  747.70%
207745 180890    -212.8827   131      -44.0000     -372.9899 32040405  747.70%
208953 181296     -86.9530    56      -44.0000     -372.9899 32078113  747.70%
209931 181837     -93.0117   192      -44.0000     -372.9480 32163706  747.61%
210844 182022    -195.7135   130      -44.0000     -372.9480 32157809  747.61%
211479 182394    -336.0640   243      -44.0000     -372.8824 32214463  747.46%
211879 183270    -333.1627   209      -44.0000     -372.8748 32262683  747.44%
Elapsed time = 646.29 sec. (482797.42 ticks, tree = 8350.07 MB, solutions = 20)
Nodefile size = 6294.05 MB (5672.22 MB after compression)
212147 184598    -363.4645  1062      -44.0000     -372.8748 32370505  747.44%
212919 185068    -288.2498   184      -44.0000     -372.8748 32431657  747.44%
214028 185646    -210.1929   142      -44.0000     -372.8748 32487431  747.44%
214899 185756    -200.4004   137      -44.0000     -372.8600 32475142  747.41%
```

```
215323 186568     -146.7879   101      -44.0000     -372.8563 32572067  747.40%
215585 186646     -265.0594   174      -44.0000     -372.8430 32582774  747.37%
215930 186866     -296.3604   233      -44.0000     -372.8430 32646715  747.37%
216342 188005     -368.3260  1030      -44.0000     -372.8430 32726916  747.37%
216864 188736     -183.1399   110      -44.0000     -372.8430 32848795  747.37%
217090 189090     -331.5462   245      -44.0000     -372.8430 32903193  747.37%
Elapsed time = 697.47 sec. (521071.74 ticks, tree = 8599.97 MB, solutions = 20)
Nodefile size = 6544.44 MB (5890.61 MB after compression)
217790 188686     -323.9812   247      -44.0000     -372.8014 32870258  747.28%
218356 189541     -133.4137    76      -44.0000     -372.7773 32936831  747.22%
219174 190551     -351.0221   300      -44.0000     -372.7773 33038249  747.22%
219578 190300     -368.7349   934      -44.0000     -372.7684 33027649  747.20%
219598 190825     -355.7343   627      -44.0000     -372.7631 33100093  747.19%
219718 191769     -139.0102    86      -44.0000     -372.7377 33251637  747.13%
220184 191764     -131.8059   121      -44.0000     -372.7377 33230928  747.13%
221011 192191     -217.5934   136      -44.0000     -372.7272 33365455  747.11%
221677 192658     -312.0576   207      -44.0000     -372.7272 33417939  747.11%
222408 192605     -131.1298    82      -44.0000     -372.6994 33406887  747.04%
Elapsed time = 751.00 sec. (560245.75 ticks, tree = 8875.72 MB, solutions = 20)
Nodefile size = 6819.28 MB (6143.16 MB after compression)
222807 193252     -351.8520   359      -44.0000     -372.6994 33474914  747.04%
223697 193819     -368.2402  1014      -44.0000     -372.6705 33555864  746.98%
224291 194508     -168.4572   113      -44.0000     -372.6705 33597439  746.98%
224688 194980     -328.9159   330      -44.0000     -372.6705 33680048  746.98%
225604 195221     -350.0778   362      -44.0000     -372.6431 33710002  746.92%
226659 196294     -277.8216   183      -44.0000     -372.6029 33779087  746.82%
227209 195824     -306.6847   195      -44.0000     -372.6029 33766707  746.82%
228433 197223     -367.8317   689      -44.0000     -372.5677 33854373  746.74%
229269 199080     -361.1116   655      -44.0000     -372.5534 34022057  746.71%
230336 199294     -175.2973   112      -44.0000     -372.5531 34046870  746.71%
Elapsed time = 804.93 sec. (599059.75 ticks, tree = 9113.38 MB, solutions = 20)
Nodefile size = 7058.01 MB (6351.40 MB after compression)
231216 200588     -358.3446   489      -44.0000     -372.5531 34129659  746.71%
231583 200216     -268.3678   255      -44.0000     -372.5531 34115070  746.71%
232305 201798      -46.5832    26      -44.0000     -372.5531 34219507  746.71%
233137 202370     -185.0193   120      -44.0000     -372.5031 34307455  746.60%
234418 201984     -225.0413   192      -44.0000     -372.4962 34280003  746.58%
235315 203798     -343.5671   300      -44.0000     -372.4823 34427805  746.55%
235540 203201     -194.1673   132      -44.0000     -372.4823 34396450  746.55%
```

```
236303 204300      -90.3678    54      -44.0000     -372.4732 34472118  746.53%
236745 204491     -353.6942   922      -44.0000     -372.4732 34519696  746.53%
237725 205433     -362.9104   718      -44.0000     -372.4587 34591948  746.50%
Elapsed time = 858.28 sec. (637821.53 ticks, tree = 9338.06 MB, solutions = 20)
Nodefile size = 7269.93 MB (6536.27 MB after compression)
238274 205925      -85.8155    50      -44.0000     -372.4587 34647302  746.50%
238981 207487     -231.9881   149      -44.0000     -372.3994 34779028  746.36%
239878 207765      -93.4593    61      -44.0000     -372.3994 34786500  746.36%
240120 207756     -365.9616   411      -44.0000     -372.3994 34822268  746.36%
240478 209365     -199.8041   130      -44.0000     -372.3584 34940305  746.27%
240821 209539     -360.1367   638      -44.0000     -372.3584 34972410  746.27%
241271 209541     -363.1588  1122      -44.0000     -372.3584 34983161  746.27%
241424 210053     -361.2374   950      -44.0000     -372.3584 35084084  746.27%
241576 210292     -347.5688   297      -44.0000     -372.3584 35112261  746.27%
241997 210422     -368.2257  1017      -44.0000     -372.3584 35145629  746.27%
Elapsed time = 912.88 sec. (676882.31 ticks, tree = 9709.04 MB, solutions = 20)
Nodefile size = 7655.42 MB (6887.57 MB after compression)
242245 210584     -240.9517   157      -44.0000     -372.3584 35171767  746.27%
242570 210687     -338.0566   350      -44.0000     -372.3584 35275535  746.27%
243231 210809     -332.0380   238      -44.0000     -372.2883 35284325  746.11%
243525 211377     -366.4540   682      -44.0000     -372.2883 35363030  746.11%
243864 211549     -332.6650   319      -44.0000     -372.2883 35413331  746.11%
244343 212034     -284.4207   206      -44.0000     -372.2542 35461002  746.03%
244916 211665     -371.1470  1019      -44.0000     -372.2542 35425781  746.03%
245241 213063     -339.6566   564      -44.0000     -372.2542 35635322  746.03%
245969 213431     -346.9792   377      -44.0000     -372.2542 35676293  746.03%
246514 214170     -356.2338   419      -44.0000     -372.2542 35731859  746.03%
Elapsed time = 966.08 sec. (716168.10 ticks, tree = 9727.48 MB, solutions = 20)
Nodefile size = 7670.55 MB (6894.27 MB after compression)
247304 214362     -248.7154   181      -44.0000     -372.1984 35793183  745.91%
247544 214195     -368.2592  1074      -44.0000     -372.1984 35773514  745.91%
248320 215215     -339.6080   224      -44.0000     -372.1984 35912774  745.91%
248943 215127     -219.3915   150      -44.0000     -372.1939 35887771  745.90%
249564 215696     -329.7974   226      -44.0000     -372.1939 35961847  745.90%
250132 216976     -264.5542   167      -44.0000     -372.1916 36040514  745.89%
250395 216722     -370.6489   959      -44.0000     -372.1916 36031786  745.89%

Performing restart 2
```

```
Repeating presolve.
Tried aggregator 1 time.
Reduced MIP has 3556 rows, 5459 columns, and 23781 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (12.05 ticks)
Tried aggregator 1 time.
Reduced MIP has 3556 rows, 5459 columns, and 23781 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (16.72 ticks)
Represolve time = 1.99 sec. (423.12 ticks)
250594     0    -385.6923  1361    -44.0000     Cuts: 281 36368218  745.89%
250594     0    -385.5894  1250    -44.0000      Cuts: 88 36373095  745.89%
250594     0    -385.5320  1275    -44.0000     Cuts: 631 36377740  745.89%
250594     0    -385.4713  1249    -44.0000     Cuts: 545 36381282  745.89%
250594     0    -385.4204  1259    -44.0000     Cuts: 957 36387163  745.89%
250594     0    -385.3847  1222    -44.0000     Cuts: 654 36390902  745.89%
250594     0    -385.3577  1237    -44.0000     Cuts: 790 36394642  745.89%
250594     0    -385.3485  1245    -44.0000     Cuts: 703 36396546  745.89%
250594     0    -385.3400  1274    -44.0000     Cuts: 658 36398676  745.89%
250594     2    -385.3400  1250    -44.0000    -372.1916 36398676  745.89%
250597     5    -382.4444   787    -44.0000    -372.1916 36411834  745.89%
250602     9    -380.3559   797    -44.0000    -372.1916 36423958  745.89%
Elapsed time = 1108.28 sec. (855683.12 ticks, tree = 0.02 MB, solutions = 20)
250611     6    -378.8050   657    -44.0000    -372.1916 36417553  745.89%
250635    35    -376.0446   672    -44.0000    -372.1916 36531095  745.89%
250672    68    -370.5626   763    -44.0000    -372.1916 36616128  745.89%
250694    92    -371.9434   943    -44.0000    -372.1916 36701820  745.89%
250721   118    -362.8932   629    -44.0000    -372.1916 36801968  745.89%
250761   125    -361.9080   779    -44.0000    -372.1916 36885878  745.89%
250789   184    -368.8459   821    -44.0000    -372.1916 37004980  745.89%
250841   217    -339.4235   586    -44.0000    -372.1916 37066500  745.89%
251153   486    -210.0063   143    -44.0000    -372.1916 37133536  745.89%
251322   495    -364.4991   902    -44.0000    -372.1916 37206131  745.89%
Elapsed time = 1152.80 sec. (895288.35 ticks, tree = 14.88 MB, solutions = 20)
251351   672    -367.3628   827    -44.0000    -372.1916 37251757  745.89%
251394   715    -364.1056   761    -44.0000    -372.1916 37328615  745.89%
251440   744    -268.2901   507    -44.0000    -372.1916 37368491  745.89%
251521   826    -318.6446   749    -44.0000    -372.1916 37511071  745.89%
251833   831    -324.7711   304    -44.0000    -372.1916 37519578  745.89%
```

```
252407  1017     -289.7608  602      -44.0000     -372.1916 37636368  745.89%
252474  1569     -230.7063  364      -44.0000     -372.1916 37760627  745.89%
252551  1641     -175.7780  280      -44.0000     -372.1916 37815845  745.89%
252648  1761     -350.1193  690      -44.0000     -372.1916 37915832  745.89%
252770  1798     -297.9704  428      -44.0000     -372.1916 37931390  745.89%
Elapsed time = 1202.91 sec. (933976.92 ticks, tree = 72.71 MB, solutions = 20)
252957  1879     -365.0530  907      -44.0000     -372.1916 38019591  745.89%
253190  1961     -374.1327  746      -44.0000     -372.1916 38105061  745.89%
253209  2081     -366.6955  727      -44.0000     -372.1916 38154827  745.89%
253245  2107     -349.4859  750      -44.0000     -372.1916 38232352  745.89%
253296  2321     -323.2255  719      -44.0000     -372.1916 38306497  745.89%
253335  2350     -338.7238  810      -44.0000     -372.1916 38399274  745.89%
253431  2430     -223.8642  266      -44.0000     -372.1916 38441630  745.89%
253627  2511     -375.7077  894      -44.0000     -372.1916 38536324  745.89%
253710  2600     -267.8143  648      -44.0000     -372.1916 38634838  745.89%
253859  2807     -130.4952  121      -44.0000     -372.1916 38706683  745.89%
Elapsed time = 1250.04 sec. (972969.48 ticks, tree = 103.61 MB, solutions = 20)
253990  2793     -354.1329  866      -44.0000     -372.1916 38772365  745.89%
254125  2847     -378.1667  932      -44.0000     -372.1916 38821293  745.89%
254160  3057     -345.8537  710      -44.0000     -372.1916 38991676  745.89%
254272  3174     -338.3096  397      -44.0000     -372.1916 39057856  745.89%
254829  3402     -355.6737  381      -44.0000     -372.1916 39162730  745.89%
255039  3352     -378.1796  878      -44.0000     -372.1916 39140890  745.89%
255759  3966     -377.3962  848      -44.0000     -372.1916 39289058  745.89%
256132  4683     -376.0871  913      -44.0000     -372.1916 39411724  745.89%
256571  4897     -110.1847  135      -44.0000     -372.1916 39448784  745.89%
256899  5006     -264.7572  206      -44.0000     -372.1916 39493263  745.89%
Elapsed time = 1299.80 sec. (1011923.48 ticks, tree = 185.99 MB, solutions = 20)
257633  5503     -108.6815  304      -44.0000     -372.1916 39551337  745.89%
257704  5875     -357.2719  386      -44.0000     -372.1916 39627575  745.89%
258222  6596     -269.8295  197      -44.0000     -372.1916 39752633  745.89%
258860  6676     -377.5047  795      -44.0000     -372.1916 39771980  745.89%
259177  6867     -342.8244  368      -44.0000     -372.1916 39847164  745.89%
259604  7816     -126.7714  273      -44.0000     -372.1916 39962898  745.89%
259992  8066     -346.3133  285      -44.0000     -372.1916 40043650  745.89%
260634  8324     -250.4738  183      -44.0000     -372.1916 40101264  745.89%
261423  8587     -117.3785   72      -44.0000     -372.1916 40156633  745.89%
261811  8623        cutoff           -44.0000     -372.1916 40168545  745.89%
Elapsed time = 1345.55 sec. (1050174.00 ticks, tree = 360.71 MB, solutions = 20)
```

```
262463  9727    -346.0636   360     -44.0000     -372.1916 40305990   745.89%
262827 10015     -53.0047    53     -44.0000     -372.1916 40336812   745.89%
263497 10204    -291.6292   329     -44.0000     -372.1916 40409727   745.89%
263810 10834    -368.7024   900     -44.0000     -372.1916 40508382   745.89%
264034 11380    -299.6250   270     -44.0000     -372.1916 40589629   745.89%
264353 11408    -333.6570   364     -44.0000     -372.1916 40631990   745.89%
265209 11627    -127.5949    81     -44.0000     -372.1916 40690974   745.89%
265375 12058    -373.9214   775     -44.0000     -372.1916 40825316   745.89%
265683 12067    -374.6869   871     -44.0000     -372.1916 40813199   745.89%
266145 12871    -108.7038    66     -44.0000     -372.1916 40958008   745.89%
Elapsed time = 1392.76 sec. (1089307.50 ticks, tree = 376.25 MB, solutions = 20)
267009 13160    -339.9349   292     -44.0000     -372.1916 41042304   745.89%
267684 13451    -235.2024   155     -44.0000     -372.1916 41068056   745.89%
268135 14202    -301.8026   239     -44.0000     -372.1916 41179259   745.89%
269063 14802    -332.9360   201     -44.0000     -372.1916 41233945   745.89%
269908 15031    -151.4007   185     -44.0000     -372.1916 41298728   745.89%
270417 15902    -355.9540   424     -44.0000     -372.1916 41379785   745.89%
271179 15998    -182.1055   124     -44.0000     -372.1916 41374578   745.89%
271618 16779    -343.4644   297     -44.0000     -372.1916 41483634   745.89%
272154 17272    -266.0548   154     -44.0000     -372.1916 41561427   745.89%
272757 17853    -107.8635    54     -44.0000     -372.1916 41620379   745.89%
Elapsed time = 1441.86 sec. (1127546.03 ticks, tree = 531.02 MB, solutions = 20)
273371 18302    -282.6906   198     -44.0000     -372.1916 41702255   745.89%
274130 18595    -244.6982   252     -44.0000     -372.1916 41749235   745.89%
274538 18916    -352.0270   368     -44.0000     -372.1916 41810597   745.89%
275533 19350    -242.7152   146     -44.0000     -372.1916 41846033   745.89%
276032 19990     -54.5599    49     -44.0000     -372.1916 41908637   745.89%
276526 20374    -115.2920    72     -44.0000     -372.1916 41972219   745.89%
277076 21354    -362.0541   532     -44.0000     -372.1916 42106109   745.89%
277609 20404    -368.4605  1077     -44.0000     -372.1916 41979761   745.89%
278059 22108    -337.7553   273     -44.0000     -372.1916 42232415   745.89%
278647 22119    -320.3121   220     -44.0000     -372.1916 42214941   745.89%
Elapsed time = 1491.47 sec. (1166019.37 ticks, tree = 615.31 MB, solutions = 20)
279632 23591    -334.9430   280     -44.0000     -372.1916 42392818   745.89%
280126 23804    -128.5027    69     -44.0000     -372.1916 42401404   745.89%
280920 23955    -138.4359   120     -44.0000     -372.1916 42477580   745.89%
281437 24950    -129.1561    99     -44.0000     -372.1916 42575431   745.89%
281989 25082    -134.7455    71     -44.0000     -372.1916 42585611   745.89%
282711 25369    -371.6460   532     -44.0000     -372.1916 42618193   745.89%
```

```
283322 26147     -343.3787   304      -44.0000     -372.1916 42729297  745.89%
284664 26732     -334.3227   329      -44.0000     -372.1916 42818857  745.89%
285866 26665     -363.2964   860      -44.0000     -372.1916 42775391  745.89%
286482 28580     -247.8636   167      -44.0000     -372.1916 42941939  745.89%
Elapsed time = 1539.98 sec. (1204311.03 ticks, tree = 860.28 MB, solutions = 20)
287505 28813     -299.1811   243      -44.0000     -372.0951 42963649  745.67%
288523 29633     -250.3703   162      -44.0000     -372.0110 43033224  745.48%
289106 30046     -295.2430   201      -44.0000     -372.0110 43069346  745.48%
289455 30190     -192.9309   112      -44.0000     -372.0040 43074509  745.46%
289993 31045     -141.5293   173      -44.0000     -372.0040 43163423  745.46%
290206 31157     -348.8130   419      -44.0000     -371.9483 43202763  745.34%
290699 31651     -341.1091   335      -44.0000     -371.9469 43228780  745.33%
291317 32466     -341.1582   315      -44.0000     -371.9469 43373635  745.33%
291837 32743     -352.7835   540      -44.0000     -371.6923 43438115  744.76%
292068 32468     -351.9463   516      -44.0000     -371.6923 43398040  744.76%
Elapsed time = 1589.93 sec. (1242794.09 ticks, tree = 1076.94 MB, solutions = 20)
292671 33486     -239.0993   208      -44.0000     -371.6923 43533295  744.76%
292992 33266     -363.6098   582      -44.0000     -371.6923 43504347  744.76%
293493 33938     -118.9946   101      -44.0000     -371.5623 43606836  744.46%
293974 34166     -353.3337   727      -44.0000     -371.5062 43668357  744.33%
294519 34909     -280.2416   186      -44.0000     -371.5062 43776237  744.33%
295353 35538     -189.7857   111      -44.0000     -371.2609 43849416  743.77%
295790 35885      -52.6185    40      -44.0000     -371.2083 43882368  743.66%
296289 35883     -314.7165   258      -44.0000     -371.2083 43920204  743.66%
296578 35201     -354.8640   645      -44.0000     -371.2083 43857528  743.66%
296765 36460     -354.9554   528      -44.0000     -371.2083 44019420  743.66%
Elapsed time = 1642.27 sec. (1284198.61 ticks, tree = 1170.56 MB, solutions = 20)
296907 36344     -353.1478   725      -44.0000     -371.2083 44017102  743.66%
297436 37190     -175.1358   102      -44.0000     -371.2083 44086601  743.66%
297836 37240     -360.3308   492      -44.0000     -371.0292 44096222  743.25%
298225 37776     -368.8773   710      -44.0000     -371.0292 44237544  743.25%
298876 37904      -76.2539    71      -44.0000     -371.0292 44259745  743.25%
299088 38497     -366.8987   596      -44.0000     -371.0292 44375456  743.25%
299492 38089     -358.5517   265      -44.0000     -370.9771 44293705  743.13%
300346 38897     -311.8971   282      -44.0000     -370.9771 44428265  743.13%
300919 39134     -357.5479   819      -44.0000     -370.9771 44454488  743.13%
301172 39614     -319.6664   202      -44.0000     -370.8041 44571989  742.74%
Elapsed time = 1691.83 sec. (1323114.08 ticks, tree = 1204.52 MB, solutions = 20)
301646 39448     -344.0955   491      -44.0000     -370.8041 44557156  742.74%
```

```
301836 40335    -103.6051    83      -44.0000     -370.8041 44707703  742.74%
302225 40202    -358.3735   487      -44.0000     -370.8041 44704677  742.74%
302610 40600    -355.9007   952      -44.0000     -370.8041 44777613  742.74%
302988 41309    -298.4826   193      -44.0000     -370.6520 44872708  742.39%
303374 40766    -283.5381   167      -44.0000     -370.6520 44825751  742.39%
303891 41485    -304.3835   215      -44.0000     -370.6520 44908146  742.39%
304356 41571     -74.9176    60      -44.0000     -370.6109 44934370  742.30%
304928 42264    -364.8487   443      -44.0000     -370.4962 45035283  742.04%
305462 42397    -359.8320   501      -44.0000     -370.4951 45041146  742.03%
Elapsed time = 1741.50 sec. (1361578.50 ticks, tree = 1299.40 MB, solutions = 20)
305990 43081     -87.9339    46      -44.0000     -370.4951 45139238  742.03%
306368 43162    -215.9043   149      -44.0000     -370.4950 45145034  742.03%
307093 43334    -343.6828   419      -44.0000     -370.3971 45170187  741.81%
307363 44228    -335.0437   293      -44.0000     -370.3971 45262113  741.81%
307994 44774    -209.7137   119      -44.0000     -370.3477 45337005  741.70%
308082 44372    -360.5717  1018      -44.0000     -370.3477 45292973  741.70%
308313 44758    -359.0325   970      -44.0000     -370.3477 45372677  741.70%
308796 45146    -329.1411   285      -44.0000     -370.2988 45421832  741.59%
309247 45738     -85.4863    51      -44.0000     -370.2988 45556907  741.59%
309734 46020    -367.5729   426      -44.0000     -370.2988 45588630  741.59%
Elapsed time = 1792.12 sec. (1401098.88 ticks, tree = 1498.55 MB, solutions = 20)
310298 46140    -357.3188  1014      -44.0000     -370.1730 45686049  741.30%
310880 46723    -313.9365   262      -44.0000     -370.0978 45733688  741.13%
311618 47314    -351.6886   376      -44.0000     -370.0978 45815752  741.13%
312071 47781    -268.8162   238      -44.0000     -370.0978 45873219  741.13%
312444 47505    -244.1141   152      -44.0000     -370.0978 45846117  741.13%
313037 48077    -223.3538   252      -44.0000     -370.0978 45934014  741.13%
313489 48766    -231.3842   174      -44.0000     -370.0978 45982195  741.13%
314106 49110    -286.7892   161      -44.0000     -369.8680 46027720  740.61%
314277 49227    -352.6875   410      -44.0000     -369.7946 46049462  740.44%
315052 49499    -356.5130   502      -44.0000     -369.7890 46093606  740.43%
Elapsed time = 1844.27 sec. (1439867.53 ticks, tree = 1727.94 MB, solutions = 20)
315430 50490   infeasible            -44.0000     -369.7665 46227867  740.38%
315633 50873    -116.4103    66      -44.0000     -369.7325 46279007  740.30%
316395 50950    -319.2967   221      -44.0000     -369.7325 46305582  740.30%
317079 51065    -360.8404   415      -44.0000     -369.6889 46312413  740.20%
317677 51183    -365.7037  1061      -44.0000     -369.6668 46348889  740.15%
318344 51962    -125.6950    92      -44.0000     -369.6668 46450552  740.15%
318572 51990    -368.0280   694      -44.0000     -369.6179 46457249  740.04%
```

```
318765 52695     -357.1016  1077      -44.0000     -369.5690 46541748  739.93%
319126 52963     -352.8065   686      -44.0000     -369.5690 46586748  739.93%
319440 53430     -260.1408   161      -44.0000     -369.5690 46663375  739.93%
Elapsed time = 1896.37 sec. (1479194.25 ticks, tree = 1951.39 MB, solutions = 20)
320144 53982     -234.4145   165      -44.0000     -369.5411 46755129  739.87%
320530 53857     -207.5893   175      -44.0000     -369.5411 46726581  739.87%
320617 53926     -344.9031   756      -44.0000     -369.5411 46789304  739.87%
321019 54333     -331.2943   278      -44.0000     -369.5411 46876025  739.87%
321384 54728     -330.9338   393      -44.0000     -369.4818 46956127  739.73%
Began writing nodes to disk (directory ./cpx6hXQcQ created)
321929 55231     -205.4632   119      -44.0000     -369.4596 47068125  739.68%
322419 55580     -324.8614   213      -44.0000     -369.4596 47114860  739.68%
322789 55897     -364.3820   405      -44.0000     -369.3454 47171636  739.42%
323522 56158     -364.5998   889      -44.0000     -369.3454 47201561  739.42%
323533 56166     -341.7744   430      -44.0000     -369.3454 47208791  739.42%
Elapsed time = 1948.33 sec. (1518462.54 ticks, tree = 2111.35 MB, solutions = 20)
Nodefile size = 58.62 MB (51.63 MB after compression)
323942 57003      -96.3349    92      -44.0000     -369.3155 47332465  739.35%
324164 57093     -340.3201   295      -44.0000     -369.3155 47380106  739.35%
324358 57091     -342.8492   664      -44.0000     -369.3155 47399665  739.35%
324721 57452     -332.6673   256      -44.0000     -369.3155 47485341  739.35%
325593 57417      -80.5629   105      -44.0000     -369.2700 47458323  739.25%
325870 57756     -344.9406   339      -44.0000     -369.2662 47566012  739.24%
326635 58368     -235.1431   177      -44.0000     -369.2522 47647462  739.21%
326735 58498     -310.1259   223      -44.0000     -369.2522 47686593  739.21%
327241 58889     -332.4587   307      -44.0000     -369.2522 47744689  739.21%
328157 58732     -348.2701   337      -44.0000     -369.2483 47714755  739.20%
Elapsed time = 2000.08 sec. (1556813.49 ticks, tree = 2191.10 MB, solutions = 20)
Nodefile size = 138.10 MB (121.57 MB after compression)
328696 59366     -349.9339   591      -44.0000     -369.2483 47866301  739.20%
329258 59928     -200.9429   112      -44.0000     -369.2483 47903916  739.20%
330085 59816     -360.8325   274      -44.0000     -369.2169 47888319  739.13%
330696 60569     -251.8809   167      -44.0000     -369.1513 47944891  738.98%
331215 61510     -350.2743   253      -44.0000     -369.1513 48067414  738.98%
331643 61684     -252.4282   148      -44.0000     -369.1169 48074972  738.90%
332328 62542     -300.0368   269      -44.0000     -369.1169 48153942  738.90%
333052 62613     -172.4415   137      -44.0000     -369.1169 48170227  738.90%
333503 63456     -273.7816   225      -44.0000     -369.0920 48254726  738.85%
334319 64313     -129.4382    75      -44.0000     -369.0066 48319508  738.65%
```

```
Elapsed time = 2053.05 sec. (1595009.26 ticks, tree = 2609.90 MB, solutions = 20)
Nodefile size = 546.80 MB (482.47 MB after compression)
334526 64366     -353.2900   430      -44.0000     -369.0066 48353456  738.65%
335096 64236     -348.8633   383      -44.0000     -369.0066 48342110  738.65%
335482 64995     -357.2174   248      -44.0000     -369.0066 48410627  738.65%
335751 65112     -108.3985    85      -44.0000     -369.0066 48422213  738.65%
336342 65566     -342.3519   298      -44.0000     -369.0066 48508876  738.65%
336872 65367     -278.6137   218      -44.0000     -369.0030 48496547  738.64%
337666 66284     -241.4814   163      -44.0000     -369.0030 48624088  738.64%
338557 67101      -71.7748    33      -44.0000     -368.7571 48737948  738.08%
339421 67550     -280.2961   200      -44.0000     -368.7571 48788027  738.08%
340094 67778      -72.4334    62      -44.0000     -368.7571 48792340  738.08%
Elapsed time = 2105.71 sec. (1633306.25 ticks, tree = 2773.62 MB, solutions = 20)
Nodefile size = 694.67 MB (612.65 MB after compression)
340708 68252      -89.3731    41      -44.0000     -368.7571 48849031  738.08%
341145 68828     -235.1402   140      -44.0000     -368.7364 48907267  738.04%
342133 69534     -227.6095   155      -44.0000     -368.6620 49008465  737.87%
343080 69560        cutoff            -44.0000     -368.6620 48981554  737.87%
343436 70905     -359.4257   669      -44.0000     -368.6480 49119605  737.84%
344064 69862     -316.9504   228      -44.0000     -368.6321 49055558  737.80%
344917 71337     -358.6754   317      -44.0000     -368.6321 49158258  737.80%
345459 71450     -241.4689   183      -44.0000     -368.5854 49178803  737.69%
345806 72770     -350.6402   414      -44.0000     -368.5854 49313002  737.69%
346180 72776     -344.2606   682      -44.0000     -368.5854 49334729  737.69%
Elapsed time = 2158.28 sec. (1671605.97 ticks, tree = 3247.77 MB, solutions = 20)
Nodefile size = 1193.67 MB (1058.69 MB after compression)
346629 73045     -306.0790   188      -44.0000     -368.5714 49381248  737.66%
346989 73311     -326.8352   274      -44.0000     -368.5714 49410860  737.66%
347251 73656     -159.0263   107      -44.0000     -368.5025 49428784  737.51%
347944 74202     -186.4601   103      -44.0000     -368.4952 49535435  737.49%
348859 74293     -334.4883   288      -44.0000     -368.4952 49557222  737.49%
349336 74834      -85.2232   153      -44.0000     -368.4952 49628825  737.49%
349792 75367     -246.7459   197      -44.0000     -368.4952 49673306  737.49%
350409 75634     -214.3057   148      -44.0000     -368.4689 49693562  737.43%
351125 76103      -65.2717    23      -44.0000     -368.4689 49729789  737.43%
351528 76502     -121.4386    73      -44.0000     -368.4689 49803180  737.43%
Elapsed time = 2212.26 sec. (1709831.49 ticks, tree = 3429.06 MB, solutions = 20)
Nodefile size = 1374.50 MB (1216.81 MB after compression)
351877 76695     -210.5933   124      -44.0000     -368.3886 49818966  737.25%
```

```
*352083+76771                          -46.0000     -368.3886           700.84%
352358 77214     -203.4235   147       -46.0000     -368.3886 49867602  700.84%
352954 77661     -354.4451   635       -46.0000     -368.3848 49922905  700.84%

GUB cover cuts applied:  1479
Clique cuts applied:  53
Cover cuts applied:  4469
Implied bound cuts applied:  115
Flow cuts applied:  171
Mixed integer rounding cuts applied:  2859
Zero-half cuts applied:  135
Lift and project cuts applied:  20
Gomory fractional cuts applied:  182

Root node processing (before b&c):
Real time             =    0.00 sec. (2.63 ticks)
Parallel b&c, 8 threads:
Real time             = 2233.60 sec. (1733502.38 ticks)
Sync time (average)   =  300.51 sec.
Wait time (average)   =    0.08 sec.
------------
Total (root+branch&cut) = 2233.60 sec. (1733505.01 ticks)

------------------------------
Iteration 10
Bounds on # of cuts = 8 with [3 3 2]
Error = 54 (out of 100 instances)
Accuracy = 46
Solving time = 37.2267415 min (minutes)
Accumulated time = 68.199989864 min (minutes)

Solution status code = 104
LB on error =  -268.366653275
Relative objective gap = 7.007970723

Selected variables:
A_AGE (Continuous)
PEMLR (Categorical)
```

```
Number of selected variables = 2 (1 continuous + 1 categorical)

------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d

CPXPARAM_MIP_Strategy_File                          3
CPXPARAM_MIP_Limits_Solutions                       1
CPXPARAM_TimeLimit                                  82308.000608154296
CPXPARAM_MIP_Limits_TreeMemory                      204800

Nodes                                          Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

352957 78439    infeasible             -46.0000     -368.3667 50058943  700.80%
Elapsed time = 0.58 sec. (13.44 ticks, tree = 3578.62 MB, solutions = 21)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
352959 78441     -355.0696   622       -46.0000     -368.3667 50059517  700.80%
352960 78442     -354.9621   614       -46.0000     -368.3667 50059978  700.80%
352961 78441     -368.1422   467       -46.0000     -368.3667 50059688  700.80%
352963 78442     -366.8929   459       -46.0000     -368.3667 50061062  700.80%
352970 78443     -364.4998   478       -46.0000     -368.3667 50063349  700.80%
352991 78459     -359.1808   287       -46.0000     -368.3667 50061782  700.80%
353012 78471     -341.2399   250       -46.0000     -368.3667 50062182  700.80%
353032 78481     -314.3891   241       -46.0000     -368.3667 50062713  700.80%
353075 78464     -352.9182   243       -46.0000     -368.3667 50065349  700.80%
353290 78522     -216.3510   139       -46.0000     -368.3667 50066815  700.80%
Elapsed time = 5.58 sec. (3453.73 ticks, tree = 3574.72 MB, solutions = 21)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
353412 78478     -313.4469   240       -46.0000     -368.3065 50067622  700.67%
353582 78573     -120.4601    54       -46.0000     -368.3065 50068969  700.67%
353756 78583     -366.5572   569       -46.0000     -368.3065 50069592  700.67%
353915 78593     -350.4133   356       -46.0000     -368.3065 50071762  700.67%
354013 78638     -255.5095   182       -46.0000     -368.3065 50073098  700.67%
354172 78670     -225.7101   139       -46.0000     -368.3065 50075904  700.67%
354385 78504     -226.4890   127       -46.0000     -368.2929 50093543  700.64%
354717 78838      -68.3427    35       -46.0000     -368.2929 50076924  700.64%
354895 78735     -366.5307   385       -46.0000     -368.2929 50081410  700.64%
355013 78725     -358.3571   260       -46.0000     -368.2929 50081358  700.64%
Elapsed time = 18.04 sec. (13079.83 ticks, tree = 3596.11 MB, solutions = 21)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
355350 78840     -106.1301    61       -46.0000     -368.2929 50082313  700.64%
```

```
355421 78637     -265.3412   275      -46.0000     -368.2929 50101647  700.64%
355525 78674     -185.2515   141      -46.0000     -368.2802 50103370  700.61%
*355558+78900                          -47.0000     -368.2802            683.57%
355620 78594     -339.7121   378      -47.0000     -368.2802 50098468  683.57%
355766 78770     -294.4367   166      -47.0000     -368.2802 50106522  683.57%
356139 78635     -175.6360   123      -47.0000     -368.2802 50098267  683.57%
356248 78595     -327.9391   290      -47.0000     -368.2802 50116071  683.57%
356341 78649     -216.7224   142      -47.0000     -368.2802 50118193  683.57%
356578 78816     -170.0356   106      -47.0000     -368.2802 50108680  683.57%
356638 78453     -344.8623   449      -47.0000     -368.2802 50116537  683.57%
Elapsed time = 29.93 sec. (23092.66 ticks, tree = 3533.95 MB, solutions = 24)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
356671 78466     -341.4183   357      -47.0000     -368.2802 50117958  683.57%
356751 78750     -256.5897   150      -47.0000     -368.2802 50111786  683.57%
356870 78469     -366.3548   433      -47.0000     -368.2802 50121648  683.57%
356949 78525     -255.7729   163      -47.0000     -368.2802 50124119  683.57%
357102 78851     -349.7279   232      -47.0000     -368.2802 50117120  683.57%
*357191+78873                          -48.0000     -368.2802            667.25%
357191 78711     -367.6334  1100      -48.0000     -368.2802 50124118  667.25%
357194 78714     -367.6270  1104      -48.0000     -368.2802 50124781  667.25%
357195 78609     -342.4514   413      -48.0000     -368.2802 50139710  667.25%
357262 78665     -248.5754   138      -48.0000     -368.2802 50141684  667.25%
357380 78718     -354.8980   803      -48.0000     -368.2802 50142887  667.25%
Elapsed time = 44.43 sec. (43023.32 ticks, tree = 3542.02 MB, solutions = 27)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
357385 78720     -354.1313   745      -48.0000     -368.2802 50144502  667.25%
357389 78723     -352.5103   493      -48.0000     -368.2802 50146723  667.25%
357394 78727     -339.5890   283      -48.0000     -368.2802 50148761  667.25%
357420 78744     -332.3197   331      -48.0000     -368.2802 50149654  667.25%
357451 78769     -280.8813   168      -48.0000     -368.2802 50150722  667.25%
357488 78795     -215.9856   158      -48.0000     -368.2802 50151746  667.25%
357527 78746     -354.7789  1031      -48.0000     -368.2802 50162814  667.25%
357530 78749     -354.6699  1031      -48.0000     -368.2802 50163649  667.25%
357531 78750     -346.2256   653      -48.0000     -368.2802 50170449  667.25%
357533 78752     -344.5490   744      -48.0000     -368.2802 50171923  667.25%
Elapsed time = 55.57 sec. (57967.17 ticks, tree = 3535.25 MB, solutions = 27)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
357536 78821     -366.0749  1161      -48.0000     -368.2802 50157991  667.25%
357540 78823     -366.0599  1158      -48.0000     -368.2802 50158619  667.25%
```

```
357556 78769     -325.5245   302      -48.0000     -368.2802 50177346   667.25%
357590 78792     -291.4648   232      -48.0000     -368.2802 50178499   667.25%
357621 78817     -233.7738   198      -48.0000     -368.2802 50179962   667.25%
357636 78824     -365.1710   595      -48.0000     -368.2802 50183101   667.25%
357669 78849     -340.1584   284      -48.0000     -368.2802 50185185   667.25%
357722 78826     -361.9055  1039      -48.0000     -368.2802 50168111   667.25%
357723 78827     -354.3601   752      -48.0000     -368.2802 50176673   667.25%
357725 78829     -352.8350   745      -48.0000     -368.2802 50178651   667.25%
Elapsed time = 63.73 sec. (73838.94 ticks, tree = 3542.48 MB, solutions = 28)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
357727 78831     -351.3868   663      -48.0000     -368.2802 50180601   667.25%
357729 78833     -349.5185   509      -48.0000     -368.2802 50182598   667.25%
357733 78835     -339.0805   430      -48.0000     -368.2802 50184554   667.25%
357757 78857     -321.4356   295      -48.0000     -368.2802 50185975   667.25%
357781 78864     -367.4109   559      -48.0000     -368.2802 50189238   667.25%
357788 78868     -362.7362   469      -48.0000     -368.2802 50191101   667.25%
357803 78879     -356.6581   374      -48.0000     -368.2802 50192864   667.25%

GUB cover cuts applied:  1515
Clique cuts applied:  53
Cover cuts applied:  4487
Implied bound cuts applied:  116
Flow cuts applied:  171
Mixed integer rounding cuts applied:  3009
Zero-half cuts applied:  135
Lift and project cuts applied:  20
Gomory fractional cuts applied:  183

Root node processing (before b&c):
Real time             =    0.00 sec. (1.95 ticks)
Parallel b&c, 8 threads:
Real time             =   70.85 sec. (82977.94 ticks)
Sync time (average)   =    1.52 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =   70.85 sec. (82979.89 ticks)

------------------------------
Iteration 11
```

```
Bounds on # of cuts = 8 with [3 3 2]
Error = 52 (out of 100 instances)
Accuracy = 48
Solving time = 1.180936951 min (minutes)
Accumulated time = 69.380926815 min (minutes)

Solution status code = 104
LB on error =  -268.191364056
Relative objective gap = 6.670653418

Selected variables:
A_AGE (Continuous)
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                          3
CPXPARAM_MIP_Limits_Solutions                       1
CPXPARAM_TimeLimit                                  82237.144391113281
CPXPARAM_MIP_Limits_TreeMemory                      204800

Nodes                                             Cuts/
Node  Left     Objective  IInf  Best Integer     Best Bound    ItCnt     Gap

357813 81848    infeasible             -48.0000     -368.1914 50513898   667.07%
Elapsed time = 0.66 sec. (292.33 ticks, tree = 3726.48 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
357826 81861      -292.1446   183       -48.0000     -368.1914 50513559   667.07%
357851 81885      -234.4599   151       -48.0000     -368.1914 50514204   667.07%
357887 81913      -152.0224    89       -48.0000     -368.1909 50514540   667.06%
357920 81854      -357.2824   437       -48.0000     -368.1909 50516152   667.06%
357957 81858      -352.0901   310       -48.0000     -368.1909 50519329   667.06%
358005 81876      -328.8730   208       -48.0000     -368.1909 50519839   667.06%
358061 81952      -365.6237   549       -48.0000     -368.1909 50516426   667.06%
358123 81944      -173.5007   110       -48.0000     -368.1909 50520624   667.06%
358187 81986       -63.5680    31       -48.0000     -368.1909 50520867   667.06%
358404 81869      -356.0177   335       -48.0000     -368.1843 50525639   667.05%
Elapsed time = 4.90 sec. (3429.12 ticks, tree = 3706.40 MB, solutions = 29)
```

```
Nodefile size = 1679.11 MB (1484.78 MB after compression)
358736 81977     -104.3151    66      -48.0000     -368.1843 50527782  667.05%
359077 81930     -213.6064   155      -48.0000     -368.1843 50539357  667.05%
359402 81958     -126.7440   131      -48.0000     -368.1843 50534882  667.05%
359558 82114     -323.8779   203      -48.0000     -368.1843 50527920  667.05%
360011 82123     -110.9767    62      -48.0000     -368.1843 50534255  667.05%
360279 82251     -303.4537   198      -48.0000     -368.1843 50531448  667.05%
360674 82270     -333.9872   256      -48.0000     -368.1843 50533165  667.05%
360773 82324     -216.5179   149      -48.0000     -368.1433 50535459  666.97%
360935 81876     -334.8739   394      -48.0000     -368.1433 50554007  666.97%
361126 82233     -126.4382    85      -48.0000     -368.1433 50538997  666.97%
Elapsed time = 16.84 sec. (13063.54 ticks, tree = 3721.75 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
361224 82365     -356.3953   443      -48.0000     -368.1433 50542559  666.97%
361281 82131     -357.4859   303      -48.0000     -368.1433 50550840  666.97%
361426 82156     -326.2501   224      -48.0000     -368.1433 50553536  666.97%
361646 82220     -176.9277   120      -48.0000     -368.1433 50556001  666.97%
361770 82452     -180.0865   199      -48.0000     -368.1433 50554805  666.97%
361955 82503      -57.9050    56      -48.0000     -368.1433 50556571  666.97%
362344 82097     -142.5888    80      -48.0000     -368.1433 50569144  666.97%
362616 82168     -298.4494   201      -48.0000     -368.1433 50555327  666.97%
362791 82238     -120.0840    76      -48.0000     -368.1433 50557846  666.97%
363008 82410     -348.3597   333      -48.0000     -368.1433 50568317  666.97%
Elapsed time = 29.19 sec. (22675.86 ticks, tree = 3702.14 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
363419 82370     -120.3047    72      -48.0000     -368.1433 50561564  666.97%
363578 82189     -249.4025   251      -48.0000     -368.1433 50581892  666.97%
363716 82216     -192.8838   220      -48.0000     -368.1433 50583993  666.97%
364045 82643     -113.9610    77      -48.0000     -368.1433 50563974  666.97%
364090 82681     -358.5332   390      -48.0000     -368.1433 50576810  666.97%
364122 82699     -341.6880   311      -48.0000     -368.1433 50578930  666.97%
364284 82291     -317.6356   231      -48.0000     -368.1433 50591814  666.97%
364631 82674     -357.5447   338      -48.0000     -368.1433 50572614  666.97%
364749 82708     -296.0979   196      -48.0000     -368.1433 50574904  666.97%
364984 82786      -87.9932    99      -48.0000     -368.1433 50575721  666.97%
Elapsed time = 41.83 sec. (32254.33 ticks, tree = 3717.44 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
365223 82504     -191.5209   217      -48.0000     -368.1433 50591049  666.97%
365504 82549     -331.3050   208      -48.0000     -368.1433 50601365  666.97%
```

```
365992 82893     -127.0245    73      -48.0000     -368.1433 50588165  666.97%
366170 82544     -366.6969   623      -48.0000     -368.1433 50597281  666.97%
366176 82548     -355.5594   469      -48.0000     -368.1433 50601349  666.97%
366189 82559     -351.7782   427      -48.0000     -368.1433 50603729  666.97%
366204 82569     -339.4731   368      -48.0000     -368.1433 50607134  666.97%
366249 82599     -272.1125   282      -48.0000     -368.1433 50608232  666.97%
366396 82671     -114.3516    71      -48.0000     -368.1433 50609897  666.97%
366634 82736     -309.9270   209      -48.0000     -368.1433 50611201  666.97%
Elapsed time = 54.67 sec. (42460.70 ticks, tree = 3710.17 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
366756 82821     -111.5596    54      -48.0000     -368.1433 50612395  666.97%
366807 82858     -343.9349   258      -48.0000     -368.1433 50613675  666.97%
366896 82914     -211.1564   174      -48.0000     -368.1433 50615760  666.97%
366985 82971     -366.4920   430      -48.0000     -368.1433 50617063  666.97%
367034 82400     -351.3165   559      -48.0000     -368.1433 50587667  666.97%
367120 83037     -244.8728   179      -48.0000     -368.1433 50620481  666.97%
367337 82703     -334.1119   233      -48.0000     -368.1433 50628475  666.97%
367706 82986     -316.4094   188      -48.0000     -368.1433 50617616  666.97%
367821 83126     -356.0752   340      -48.0000     -368.1433 50627458  666.97%
368044 82503     -135.1360   111      -48.0000     -368.1433 50593666  666.97%
Elapsed time = 67.00 sec. (52139.75 ticks, tree = 3695.91 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
368238 82922     -164.7335    92      -48.0000     -368.1433 50634114  666.97%
368430 83224     -123.8483   141      -48.0000     -368.1433 50637485  666.97%
368773 83201     -128.9948    87      -48.0000     -368.1433 50629760  666.97%
368913 83264     -357.5110   311      -48.0000     -368.1433 50641918  666.97%
369098 83112     -324.3748   198      -48.0000     -368.1433 50639612  666.97%
369400 83329     -191.7452   204      -48.0000     -368.1433 50645762  666.97%
369572 83433     -223.7018   132      -48.0000     -368.1433 50636921  666.97%
369806 82380     -287.5304   169      -48.0000     -368.1433 50648326  666.97%
370042 83155     -230.0538   152      -48.0000     -368.1433 50627192  666.97%
370296 83206     -105.6802    84      -48.0000     -368.1433 50627997  666.97%
Elapsed time = 79.67 sec. (61734.30 ticks, tree = 3719.22 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
370473 83648     -363.5100   330      -48.0000     -368.1433 50644687  666.97%
370572 83690     -301.8013   207      -48.0000     -368.1433 50648101  666.97%
370729 83483     -197.3347   130      -48.0000     -368.1387 50658662  666.96%
370929 83541     -365.7080   488      -48.0000     -368.1387 50660523  666.96%
371088 83221     -351.9229   387      -48.0000     -368.1387 50653084  666.96%
```

```
371487 83670     -73.6233    44      -48.0000     -368.1387 50663896  666.96%
371836 83297    -205.4547   120      -48.0000     -368.1387 50656731  666.96%
371955 84037    -363.3737   398      -48.0000     -368.1387 50658794  666.96%
372245 84150    -104.1935    62      -48.0000     -368.1387 50660639  666.96%
372599 84174    -356.4815   416      -48.0000     -368.1387 50662713  666.96%
Elapsed time = 91.72 sec. (71418.27 ticks, tree = 3710.01 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
372758 83830    -350.2123   218      -48.0000     -368.1387 50673011  666.96%
372917 83910    -185.9764   100      -48.0000     -368.1337 50675434  666.95%
373114 82774    -318.4387   220      -48.0000     -368.1337 50678770  666.95%
373417 84320    -338.0692   224      -48.0000     -368.1337 50669801  666.95%
373666 83414    -320.7274   235      -48.0000     -368.1337 50655149  666.95%
374022 83475    -168.1748   126      -48.0000     -368.1337 50656810  666.95%
374273 84491    -280.5796   200      -48.0000     -368.1337 50676353  666.95%
374608 84074    -110.7467    74      -48.0000     -368.1337 50687542  666.95%
374870 83955    -200.9511   127      -48.0000     -368.1337 50773859  666.95%
375060 84635    -264.2193   176      -48.0000     -368.1337 50681732  666.95%
Elapsed time = 104.63 sec. (80997.62 ticks, tree = 3712.07 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
375289 83674    -313.4418   201      -48.0000     -368.1337 50666202  666.95%
375652 83029    -311.7428   205      -48.0000     -368.1337 50695634  666.95%
375861 83121    -243.7553   181      -48.0000     -368.1337 50707677  666.95%
376042 83812    -322.3605   225      -48.0000     -368.1337 50672426  666.95%
376328 83907     -76.8829    55      -48.0000     -368.1337 50673938  666.95%
376562 84043    -315.9558   248      -48.0000     -368.1337 50786727  666.95%
376701 84097    -203.0215   121      -48.0000     -368.1337 50788420  666.95%
376892 83281     -94.0053    88      -48.0000     -368.1337 50707850  666.95%
376963 84416    -300.0476   169      -48.0000     -368.1337 50708399  666.95%
377680 83473    -295.0804   190      -48.0000     -368.1337 50717425  666.95%
Elapsed time = 120.42 sec. (93442.31 ticks, tree = 3693.86 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
378589 84784     -62.4796    50      -48.0000     -368.1337 50723926  666.95%
379167 84588    -357.1111   256      -48.0000     -368.1295 50809279  666.94%
379898 84778    -210.9325   156      -48.0000     -368.1295 50814162  666.94%
381019 83619    -115.1233    68      -48.0000     -368.1295 50707029  666.94%
382720 83365    -140.2585   105      -48.0000     -368.1295 50688807  666.94%
384080 83309    -101.5742    51      -48.0000     -368.1295 50766747  666.94%
384963 83446    -105.2105    49      -48.0000     -368.1295 50774019  666.94%
386015 84519    -346.9758   297      -48.0000     -368.1265 50783476  666.93%
```

```
386910 85693     -155.1845   151      -48.0000     -368.1265 50775095  666.93%
387595 84934     -333.2850   217      -48.0000     -368.1265 50794129  666.93%
Elapsed time = 167.93 sec. (131619.11 ticks, tree = 3741.29 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
388775 86007      -55.9050    38      -48.0000     -368.1265 50790936  666.93%
389667 89849      -58.8835    63      -48.0000     -368.1265 51217466  666.93%
390428 84259     -235.6584   138      -48.0000     -368.1265 50820389  666.93%
391907 85686     -200.5898   122      -48.0000     -368.1265 50817259  666.93%
393428 86618     -190.2522   146      -48.0000     -368.1265 51023481  666.93%
394894 85686     -338.0291   262      -48.0000     -368.1265 50892802  666.93%
396235 86317     -283.0987   189      -48.0000     -368.1265 50835383  666.93%
397505 86197      -70.7395    64      -48.0000     -368.1265 50901768  666.93%
398333 86550     -347.5027   457      -48.0000     -368.1265 50846264  666.93%
399245 86427     -177.6206    95      -48.0000     -368.1265 50911461  666.93%
Elapsed time = 217.63 sec. (169797.21 ticks, tree = 3979.15 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
400219 86967     -365.8791   488      -48.0000     -368.1265 50855776  666.93%
401660 91267     -243.3707   155      -48.0000     -368.1265 51274192  666.93%
403296 87512     -341.1402   231      -48.0000     -368.1265 50866250  666.93%
404989 84983     -140.2182    86      -48.0000     -368.0929 50859564  666.86%
406525 88101     -184.9819   105      -48.0000     -368.0929 50876062  666.86%
407805 92086     -259.9844   159      -48.0000     -368.0929 51296163  666.86%
409441 86511     -258.7671   146      -48.0000     -368.0929 50913194  666.86%
411560 92832     -360.5152   318      -48.0000     -368.0929 51306048  666.86%
413551 93075      -71.0918    41      -48.0000     -368.0929 51311387  666.86%
415320 93351     -366.3324   416      -48.0000     -368.0856 51316812  666.84%
Elapsed time = 280.95 sec. (207992.61 ticks, tree = 4136.27 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
416761 93635     -356.6959   307      -48.0000     -368.0856 51321961  666.84%
417641 103611     -333.2727   267      -48.0000     -368.0856 52115151  666.84%
418995 86717      -91.4659    93      -48.0000     -368.0856 50923115  666.84%
420375 95010     -345.7725   227      -48.0000     -368.0856 51592947  666.84%
422388 97745     -208.8593   113      -48.0000     -368.0856 51806281  666.84%
*424820+95327                          -49.0000     -368.0856            651.20%
424875 86974     -117.5452    83      -49.0000     -368.0856 50941301  651.20%
426829 88296     -141.1596   108      -49.0000     -368.0856 51174273  651.20%
428842 87107      -81.6216    48      -49.0000     -368.0856 50956823  651.20%
430040 88694     -143.4552   113      -49.0000     -368.0856 51183846  651.20%
431654 88993      -56.4649    57      -49.0000     -368.0856 51187570  651.20%
```

```
Elapsed time = 330.56 sec. (246162.32 ticks, tree = 3912.30 MB, solutions = 30)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
432487 89155     -309.7494   252      -49.0000     -368.0856 51192129   651.20%
433820 98871     -248.0751   169      -49.0000     -368.0856 51844744   651.20%
434923 89508      -95.4429    54      -49.0000     -368.0856 50996457   651.20%
436455 90671     -329.4717   245      -49.0000     -368.0856 51072363   651.20%
438281 90148     -118.6082   102      -49.0000     -368.0856 51006030   651.20%
439742 90497     -207.3705   167      -49.0000     -368.0856 51216254   651.20%
441567 90674     -173.8533   102      -49.0000     -368.0856 51016082   651.20%
443828 91216     -303.3454   206      -49.0000     -368.0856 51223635   651.20%
445236 87736     -175.7545    94      -49.0000     -368.0856 51043195   651.20%
447049 91633     -313.8024   195      -49.0000     -368.0856 51113941   651.20%
Elapsed time = 373.44 sec. (284339.53 ticks, tree = 4204.39 MB, solutions = 30)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
447980 100629     -348.9983   289      -49.0000     -368.0856 51894673   651.20%
449086 92335     -127.1360    75      -49.0000     -368.0856 51244067   651.20%
449528 92362     -357.3279  1052      -49.0000     -368.0856 51255961   651.20%

GUB cover cuts applied:  1587
Clique cuts applied:  53
Cover cuts applied:  4561
Implied bound cuts applied:  116
Flow cuts applied:  178
Mixed integer rounding cuts applied:  3530
Zero-half cuts applied:  136
Lift and project cuts applied:  20
Gomory fractional cuts applied:  183

Root node processing (before b&c):
Real time             =    0.00 sec. (2.15 ticks)
Parallel b&c, 8 threads:
Real time             =  430.29 sec. (305295.57 ticks)
Sync time (average)   =   41.19 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  430.29 sec. (305297.72 ticks)

------------------------------
Iteration 12
```

```
Bounds on # of cuts = 8 with [3 3 2]
Error = 51 (out of 100 instances)
Accuracy = 49
Solving time = 7.171601351 min (minutes)
Accumulated time = 76.552528166 min (minutes)

Solution status code = 104
LB on error =  -267.975324274
Relative objective gap = 6.509700495

Selected variables:
A_AGE (Continuous)
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                      3
CPXPARAM_MIP_Limits_Solutions                   1
CPXPARAM_TimeLimit                              81806.848310058587
CPXPARAM_MIP_Limits_TreeMemory                  204800

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

449529 148551    infeasible           -49.0000     -367.9753 54370598  650.97%
Elapsed time = 0.47 sec. (14.98 ticks, tree = 8107.53 MB, solutions = 30)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
449531 148553     -359.5659   442      -49.0000     -367.9753 54371140  650.97%
449538 148551    infeasible           -49.0000     -367.9753 54371316  650.97%
449555 148565     -356.7244   318      -49.0000     -367.9753 54371964  650.97%
449593 148577     -332.7352   218      -49.0000     -367.9753 54373247  650.97%
449639 148602     -280.7380   198      -49.0000     -367.9753 54373435  650.97%
449702 148606     -260.2627   157      -49.0000     -367.9753 54373161  650.97%
449786 148649     -166.4203   107      -49.0000     -367.9753 54373940  650.97%
449880 148675      -94.9784    61      -49.0000     -367.9753 54374029  650.97%
449971 148638     -203.4032   129      -49.0000     -367.9753 54375734  650.97%
450059 148698     -366.2099   443      -49.0000     -367.9753 54375106  650.97%
Elapsed time = 5.04 sec. (3168.00 ticks, tree = 8124.01 MB, solutions = 30)
```

```
Nodefile size = 6060.88 MB (5290.89 MB after compression)
450236 148594     -295.4153   184      -49.0000     -367.9753 54382327  650.97%
450577 148682      -63.8978    27      -49.0000     -367.9753 54385978  650.97%
450591 148559     -360.5034   415      -49.0000     -367.8207 54398193  650.65%
450738 148908     -173.4438   111      -49.0000     -367.8207 54383205  650.65%
450900 148662     -146.4658   101      -49.0000     -367.8207 54401032  650.65%
451012 148976     -333.3717   213      -49.0000     -367.8207 54385969  650.65%
451296 148560     -363.7896   978      -49.0000     -367.6854 54392980  650.38%
451342 149129     -304.8566   181      -49.0000     -367.6854 54388385  650.38%
451481 148830     -361.6500   361      -49.0000     -367.6854 54396382  650.38%
451603 148878     -283.0614   180      -49.0000     -367.6854 54397899  650.38%
Elapsed time = 17.82 sec. (12954.41 ticks, tree = 8108.39 MB, solutions = 30)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
451826 148953      -82.9050    50      -49.0000     -367.6854 54398543  650.38%
451879 148704     -340.0657   313      -49.0000     -367.6854 54393842  650.38%
451961 149414     -296.1621   239      -49.0000     -367.6854 54395518  650.38%
452167 148607     -276.8603   214      -49.0000     -367.6854 54403955  650.38%
452428 149031     -219.7767   147      -49.0000     -367.6854 54406146  650.38%
452701 148652     -365.3107   433      -49.0000     -367.6854 54406178  650.38%
453008 148875     -265.3827   181      -49.0000     -367.6854 54403380  650.38%
453289 149184     -154.6563    92      -49.0000     -367.6854 54411487  650.38%
453348 148960     -360.0414   372      -49.0000     -367.6854 54406637  650.38%
453502 149046     -148.5781    74      -49.0000     -367.6854 54407919  650.38%
Elapsed time = 30.74 sec. (22572.71 ticks, tree = 8146.19 MB, solutions = 30)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
453759 148853     -256.7948   204      -49.0000     -367.6854 54415433  650.38%
453922 148937      -60.9847    87      -49.0000     -367.6854 54416165  650.38%
454060 149366     -363.9560   517      -49.0000     -367.6854 54420697  650.38%
*454067+148947                           -50.0000     -367.6854            635.37%
454103 149399     -314.6991   203      -50.0000     -367.6854 54422606  635.37%
454237 149500      -56.4004    29      -50.0000     -367.6854 54423429  635.37%
454247 148825     -356.6694   887      -50.0000     -367.6854 54420679  635.37%
454277 148835     -290.6358   185      -50.0000     -367.6854 54422588  635.37%
454414 148923      -67.9049    38      -50.0000     -367.6854 54423303  635.37%
454472 148930     -363.1861   506      -50.0000     -367.6854 54424890  635.37%
454545 149615      -91.8766    82      -50.0000     -367.6854 54431081  635.37%
Elapsed time = 43.16 sec. (32219.69 ticks, tree = 8192.55 MB, solutions = 31)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
454566 149628     -364.7786   412      -50.0000     -367.6854 54432926  635.37%
```

```
454641 149685    -257.6134   147      -50.0000     -367.6854 54434532  635.37%
454765 149232    -338.9140   319      -50.0000     -367.6854 54425621  635.37%
454818 149263    -264.9478   165      -50.0000     -367.6854 54427210  635.37%
455006 148623    -232.9872   171      -50.0000     -367.6854 54453546  635.37%
455113 148698    -365.3190   406      -50.0000     -367.6854 54454977  635.37%
455205 148741    -298.9809   232      -50.0000     -367.6854 54456259  635.37%
455387 149424    -232.1075   128      -50.0000     -367.6854 54435736  635.37%
455507 148735    -264.2029   170      -50.0000     -367.6854 54427522  635.37%
455726 149833    -203.7847   140      -50.0000     -367.6854 54447876  635.37%
Elapsed time = 54.10 sec. (41946.00 ticks, tree = 8217.64 MB, solutions = 32)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
455921 149884    infeasible            -50.0000     -367.6854 54452377  635.37%
455956 149909    -340.9434   221      -50.0000     -367.6854 54453965  635.37%
456118 148703    -322.7887   332      -50.0000     -367.6854 54448276  635.37%
456211 150028    -361.5807   311      -50.0000     -367.6854 54457854  635.37%
456551 150147     -90.9050    48      -50.0000     -367.6854 54458849  635.37%
456710 150218    -244.2240   146      -50.0000     -367.6854 54460397  635.37%
456937 150290    -365.6604   620      -50.0000     -367.6854 54461963  635.37%
457104 150332    -301.2754   178      -50.0000     -367.6854 54463828  635.37%
457325 149253    -317.2975   220      -50.0000     -367.6854 54475276  635.37%
457456 149351     -66.9050    55      -50.0000     -367.6854 54475951  635.37%
Elapsed time = 68.03 sec. (53360.20 ticks, tree = 8134.99 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
457550 149392    -299.9797   180      -50.0000     -367.6854 54477445  635.37%
457686 148828    -349.3764   432      -50.0000     -367.6854 54460618  635.37%
457810 148869    -286.1150   166      -50.0000     -367.6854 54462183  635.37%
458021 148956    -366.7730  1041      -50.0000     -367.6854 54465966  635.37%
458023 148958    -365.0671   968      -50.0000     -367.6854 54471615  635.37%
458024 148959    -363.9372  1032      -50.0000     -367.6854 54476003  635.37%
458026 148959    infeasible            -50.0000     -367.6854 54482253  635.37%
458028 149619    -355.0212   967      -50.0000     -367.6854 54505490  635.37%
458029 149620    -354.8428   952      -50.0000     -367.6854 54509299  635.37%
458031 148960    -361.1371  1077      -50.0000     -367.6854 54490873  635.37%
Elapsed time = 75.01 sec. (76144.16 ticks, tree = 8099.72 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
458035 149623    -338.0811   587      -50.0000     -367.6854 54515789  635.37%
458072 149654    -292.3925   206      -50.0000     -367.6854 54517524  635.37%
458195 149745    -366.2947   371      -50.0000     -367.6854 54518192  635.37%
458268 149801    -265.0918   206      -50.0000     -367.6854 54519721  635.37%
```

```
458362 149969     -339.0310   358      -50.0000     -367.6854 54499208  635.37%
458394 148993     -294.8755   208      -50.0000     -367.6854 54501358  635.37%
458507 149871     -352.6250   646      -50.0000     -367.6854 54535166  635.37%
458509 149873     -348.5649   612      -50.0000     -367.6854 54536702  635.37%
458514 149878     -344.9235   428      -50.0000     -367.6854 54539075  635.37%
458536 149895     -297.6408   238      -50.0000     -367.6854 54541041  635.37%
Elapsed time = 88.09 sec. (94500.64 ticks, tree = 8197.13 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
458680 149994     -364.9267   362      -50.0000     -367.6854 54542471  635.37%
458801 149115     -328.4475   206      -50.0000     -367.6854 54526877  635.37%
459008 150143     -344.6698   288      -50.0000     -367.6854 54544620  635.37%
459201 150256     -366.0108   502      -50.0000     -367.6854 54545677  635.37%
459262 150301     -288.3912   191      -50.0000     -367.6854 54547706  635.37%
459384 149217        cutoff            -50.0000     -367.6854 54536299  635.37%
459407 150400     -355.7017   347      -50.0000     -367.6854 54550553  635.37%
459462 150443     -285.5415   194      -50.0000     -367.6854 54552575  635.37%
459552 150512      -80.8691    63      -50.0000     -367.6854 54553583  635.37%
459612 150559     -306.0035   185      -50.0000     -367.6854 54555246  635.37%
Elapsed time = 95.25 sec. (104655.04 ticks, tree = 8273.17 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
459757 150659     -364.0543   363      -50.0000     -367.6854 54556163  635.37%
460012 150786     -365.0957   367      -50.0000     -367.6854 54557236  635.37%
460166 150852     -257.4208   157      -50.0000     -367.6854 54558763  635.37%
460271 150928     -364.7451   440      -50.0000     -367.6854 54559507  635.37%
460315 150961     -322.3830   231      -50.0000     -367.6854 54560849  635.37%
460444 151056     -365.3064   533      -50.0000     -367.6854 54562520  635.37%
460460 151063     -349.8631   236      -50.0000     -367.6854 54564641  635.37%
460548 151134     -168.2526   125      -50.0000     -367.6854 54565692  635.37%
460596 149345     -353.9889   773      -50.0000     -367.6854 54557078  635.37%
460634 149374     -285.4250   215      -50.0000     -367.6854 54563745  635.37%
Elapsed time = 104.38 sec. (117804.09 ticks, tree = 8133.27 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
460972 151200     -309.7938   276      -50.0000     -367.6854 54579043  635.37%
460986 149605     -354.4270   858      -50.0000     -367.6854 54576765  635.37%
461156 149721     -353.2440   644      -50.0000     -367.6854 54594267  635.37%
461200 149747     -319.7503   298      -50.0000     -367.6854 54601578  635.37%
461459 149970     -140.8536    83      -50.0000     -367.6854 54607404  635.37%
461869 150271     -362.2076   370      -50.0000     -367.6854 54611721  635.37%
462205 150520     -348.8006   380      -50.0000     -367.6854 54618159  635.37%
```

```
462684 150874     -141.8029    82      -50.0000     -367.6854 54623422  635.37%
462904 151045     -365.6643   568      -50.0000     -367.6854 54630449  635.37%
463109 151192     -349.4642   263      -50.0000     -367.6854 54638262  635.37%
Elapsed time = 136.21 sec. (163970.28 ticks, tree = 8327.89 MB, solutions = 34)
Nodefile size = 6060.88 MB (5290.89 MB after compression)

GUB cover cuts applied:  1636
Clique cuts applied:  53
Cover cuts applied:  4620
Implied bound cuts applied:  117
Flow cuts applied:  182
Mixed integer rounding cuts applied:  3798
Zero-half cuts applied:  137
Lift and project cuts applied:  21
Gomory fractional cuts applied:  183

Root node processing (before b&c):
Real time             =    0.00 sec. (2.40 ticks)
Parallel b&c, 8 threads:
Real time             =  139.89 sec. (165844.88 ticks)
Sync time (average)   =    3.07 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  139.89 sec. (165847.28 ticks)

------------------------------
Iteration 13
Bounds on # of cuts = 8 with [3 3 2]
Error = 50 (out of 100 instances)
Accuracy = 50
Solving time = 2.331538167 min (minutes)
Accumulated time = 78.884066333 min (minutes)

Solution status code = 104
LB on error =  -267.498135184
Relative objective gap = 6.349962704

Selected variables:
A_AGE (Continuous)
```

```
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                          3
CPXPARAM_MIP_Limits_Solutions                       1
CPXPARAM_TimeLimit                                  81666.956020019526
CPXPARAM_MIP_Limits_TreeMemory                      204800

Nodes                                           Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

463135 158775    infeasible            -50.0000     -367.4981 55198048  635.00%
Elapsed time = 0.72 sec. (15.17 ticks, tree = 9214.61 MB, solutions = 35)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
463136 158777     -366.5895   490      -50.0000     -367.4981 55198583  635.00%
463140 158777     -366.5176   642      -50.0000     -367.4981 55198925  635.00%
463162 158789     -348.1658   230      -50.0000     -367.4981 55199716  635.00%
463191 158808     -305.6908   217      -50.0000     -367.4981 55200151  635.00%
463231 158839     -228.0707   125      -50.0000     -367.4981 55200362  635.00%
463277 158868     -155.1797    87      -50.0000     -367.4981 55200885  635.00%
463346 158903      -73.9050    40      -50.0000     -367.4981 55201169  635.00%
463386 158807     -332.2260   227      -50.0000     -367.4981 55203386  635.00%
463443 158821     -309.8742   204      -50.0000     -367.4981 55202374  635.00%
463885 158912      -57.9050    30      -50.0000     -367.4981 55206450  635.00%
Elapsed time = 4.78 sec. (3333.40 ticks, tree = 9185.11 MB, solutions = 35)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
463977 158951     -311.4922   247      -50.0000     -367.4981 55207360  635.00%
464319 159014     -129.0656    74      -50.0000     -367.4981 55211007  635.00%
464400 159039     -365.9692   556      -50.0000     -367.4981 55214011  635.00%
464435 158914     -363.0478   611      -50.0000     -367.4981 55217781  635.00%
464654 158929     -332.7367   352      -50.0000     -367.4981 55213624  635.00%
464900 158970     -238.0384   158      -50.0000     -367.3236 55215938  634.65%
465154 159315      -57.9050    43      -50.0000     -367.3236 55221298  634.65%
465181 159068     -320.7091   311      -50.0000     -367.3236 55222588  634.65%
465201 158920     -354.1757   744      -50.0000     -367.3236 55218060  634.65%
465256 159111     -246.3611   193      -50.0000     -367.3236 55228446  634.65%
Elapsed time = 18.42 sec. (13757.59 ticks, tree = 9195.97 MB, solutions = 35)
```

```
Nodefile size = 7167.73 MB (6279.59 MB after compression)
465358 159084     -314.4182   271      -50.0000     -367.3236 55226164  634.65%
465456 159131     -187.6688   114      -50.0000     -367.3236 55228695  634.65%
465661 158957     -277.9212   163      -50.0000     -367.3236 55224025  634.65%
466060 159341     -322.8122   208      -50.0000     -367.3236 55231554  634.65%
466373 159214     -320.7883   207      -50.0000     -367.3236 55238808  634.65%
466710 159450     -363.6421   406      -50.0000     -367.3236 55235082  634.65%
467092 159174      -82.9050    46      -50.0000     -367.2274 55234189  634.45%
467517 159450      -80.0285    38      -50.0000     -367.2274 55243721  634.45%
467643 159181     -361.5120   332      -50.0000     -367.2274 55237667  634.45%
467857 159282     -137.5505    86      -50.0000     -367.2274 55239206  634.45%
Elapsed time = 30.58 sec. (23322.97 ticks, tree = 9206.18 MB, solutions = 35)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
468131 159579      -98.6959    54      -50.0000     -367.2274 55248828  634.45%
468495 159424     -138.5116    92      -50.0000     -367.2274 55251419  634.45%
468860 159757     -299.5947   187      -50.0000     -367.2274 55249968  634.45%
469263 159717     -102.4586    55      -50.0000     -367.2274 55254216  634.45%
469473 159677     -150.4201    83      -50.0000     -367.2274 55251829  634.45%
469748 159820     -174.4052   108      -50.0000     -367.2274 55257568  634.45%
470173 159481     -323.6713   253      -50.0000     -367.2274 55252810  634.45%
470415 158856     -199.7805   124      -50.0000     -367.2274 55276184  634.45%
470751 159959     -175.7107    99      -50.0000     -367.2274 55263101  634.45%
471015 159827     -151.8560    89      -50.0000     -367.2274 55267815  634.45%
Elapsed time = 42.21 sec. (32903.35 ticks, tree = 9179.86 MB, solutions = 35)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
471249 160104     -129.7341    76      -50.0000     -367.2274 55266272  634.45%
471728 159717        cutoff            -50.0000     -367.2274 55262790  634.45%
472043 158873     -146.7093    92      -50.0000     -367.2274 55269576  634.45%
472112 159045     -359.1444   299      -50.0000     -367.2274 55288895  634.45%
472255 159107     -255.2068   161      -50.0000     -367.2274 55290947  634.45%
472607 160018     -340.2480   214      -50.0000     -367.2274 55279581  634.45%
473049 160115     -107.4381    59      -50.0000     -367.2274 55281245  634.45%
473256 160127     -327.8756   214      -50.0000     -367.2274 55275796  634.45%
473588 159992      -67.9050    32      -50.0000     -367.2274 55278335  634.45%
473847 159971     -349.1251   284      -50.0000     -367.2274 55276168  634.45%
Elapsed time = 53.92 sec. (42468.69 ticks, tree = 9219.60 MB, solutions = 35)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
*473936+160266                              -51.0000     -367.2274           620.05%
474206 160073     -106.9895    61      -51.0000     -367.2274 55277413  620.05%
```

```
474463 160635     -153.2612    94      -51.0000     -367.2274 55286212  620.05%
474720 160190     -231.7403   139      -51.0000     -367.2274 55285078  620.05%
474998 160214     -188.9340   119      -51.0000     -367.2274 55293399  620.05%
475115 158909     -351.2163   434      -51.0000     -367.2274 55286348  620.05%
475182 160297     -322.9094   208      -51.0000     -367.2274 55297449  620.05%
475430 159398     -178.7548   109      -51.0000     -367.2274 55314927  620.05%
475645 160241     -343.1800   338      -51.0000     -367.2274 55290066  620.05%
475689 159453     -352.9342   244      -51.0000     -367.2274 55318299  620.05%
475854 159546     -132.8329    74      -51.0000     -367.2274 55319648  620.05%
Elapsed time = 65.35 sec. (52182.49 ticks, tree = 9149.24 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
476031 160718     -240.2005   152      -51.0000     -367.2274 55306433  620.05%
476142 159580     -362.2827   332      -51.0000     -367.2274 55324358  620.05%
476249 160829     -310.6718   209      -51.0000     -367.2274 55309938  620.05%
476542 159639     -255.0189   186      -51.0000     -367.2274 55330168  620.05%
476682 159724     -364.8578   329      -51.0000     -367.2274 55332953  620.05%
476863 159830     -123.2319    72      -51.0000     -367.2274 55334306  620.05%
477115 159915     -264.5046   167      -51.0000     -367.2274 55335820  620.05%
477332 159993     -363.7070   330      -51.0000     -367.2274 55337385  620.05%
477539 160005     -346.0468   269      -51.0000     -367.2274 55340473  620.05%
477743 160033     -289.9295   263      -51.0000     -367.2274 55343355  620.05%
Elapsed time = 76.10 sec. (61944.06 ticks, tree = 9151.21 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
478067 160528      -58.4099    23      -51.0000     -367.2274 55320438  620.05%
478272 161231     -353.4015   234      -51.0000     -367.2274 55327993  620.05%
478528 161319     -127.3948    80      -51.0000     -367.2274 55330121  620.05%
478842 160780     -107.5241    73      -51.0000     -367.2274 55324854  620.05%
479065 160251     -364.3253   339      -51.0000     -367.2274 55353325  620.05%
479151 160321     -214.6277   139      -51.0000     -367.2274 55354988  620.05%
479262 160382     -363.8436   407      -51.0000     -367.2274 55356639  620.05%
479450 159282      -67.9050    30      -51.0000     -367.2274 55326580  620.05%
479573 160516      -80.8811    56      -51.0000     -367.2274 55359174  620.05%
479698 159343     -257.4662   179      -51.0000     -367.2274 55329998  620.05%
Elapsed time = 87.26 sec. (71569.74 ticks, tree = 9167.39 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
479968 159410      -78.9050    42      -51.0000     -367.2274 55331365  620.05%
480111 160658     -364.4200   444      -51.0000     -367.2274 55364600  620.05%
480282 159204     -331.5965   250      -51.0000     -367.2274 55319373  620.05%
480731 161741     -101.9345    64      -51.0000     -367.2274 55352367  620.05%
```

```
480977 160912      -99.4795    61      -51.0000     -367.2274 55369544  620.05%
481190 161873      -98.8474    60      -51.0000     -367.2274 55355666  620.05%
481381 159573     -347.1083   234      -51.0000     -367.2274 55341855  620.05%
481707 160908     -133.3562    68      -51.0000     -367.2274 55346119  620.05%
481897 160938     -363.3551   308      -51.0000     -367.2274 55348000  620.05%
481964 162036     -343.0073   212      -51.0000     -367.2274 55364517  620.05%
Elapsed time = 98.33 sec. (81154.62 ticks, tree = 9209.33 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
482104 162103     -209.0701   120      -51.0000     -367.2274 55366952  620.05%
482251 161057     -106.7135    99      -51.0000     -367.2274 55353243  620.05%
482354 162205     -281.0030   193      -51.0000     -367.2274 55370235  620.05%
482515 161109     -330.1069   237      -51.0000     -367.2274 55357746  620.05%
482708 162411      -81.9050    43      -51.0000     -367.2274 55372148  620.05%
482820 162458     -269.5278   203      -51.0000     -367.2274 55374343  620.05%
482988 161088     -309.6921   433      -51.0000     -367.2274 55399414  620.05%
483039 162556     -348.2095   215      -51.0000     -367.2274 55378317  620.05%
483226 162656      -89.9044    79      -51.0000     -367.2274 55379615  620.05%
483938 161562     -209.0311   125      -51.0000     -367.2274 55374982  620.05%
Elapsed time = 113.95 sec. (93675.38 ticks, tree = 9187.73 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
484586 159413     -172.3045   113      -51.0000     -367.2274 55359518  620.05%
485529 161722     -101.4604    54      -51.0000     -367.2274 55433697  620.05%
486131 161941     -232.0853   139      -51.0000     -367.2274 55443663  620.05%
486946 162526      -81.6550    59      -51.0000     -367.2274 55404513  620.05%
487527 162760     -156.1149    92      -51.0000     -367.2274 55412036  620.05%
488098 162756     -160.2393    94      -51.0000     -367.2274 55463473  620.05%
488873 163196     -364.3675   591      -51.0000     -367.2274 55428823  620.05%
489167 163437     -131.5328    86      -51.0000     -367.2274 55437245  620.05%
489499 163605     -353.8026   297      -51.0000     -367.2274 55443068  620.05%
490304 163909     -255.8353   167      -51.0000     -367.2274 55449013  620.05%
Elapsed time = 143.38 sec. (132189.37 ticks, tree = 9198.49 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
490905 160344     -153.9110    84      -51.0000     -367.2274 55422663  620.05%
491333 160512     -362.6557   903      -51.0000     -367.2274 55435036  620.05%
491496 164109      -56.2383    27      -51.0000     -367.2274 55478391  620.05%
492194 160785      -95.2200    49      -51.0000     -367.2274 55448138  620.05%
492741 160943     -352.7760   226      -51.0000     -367.2274 55453097  620.05%
493057 164745     -364.0406  1032      -51.0000     -367.2274 55509590  620.05%
493058 164746     -359.9377   895      -51.0000     -367.2274 55516078  620.05%
```

```
493120 164797     -239.5931   151      -51.0000     -367.2274 55522135  620.05%
493562 165115     -101.7102    52      -51.0000     -367.2274 55526531  620.05%
493915 165390     -364.7521   472      -51.0000     -367.2274 55531114  620.05%
Elapsed time = 181.06 sec. (181989.34 ticks, tree = 9277.64 MB, solutions = 37)
Nodefile size = 7167.73 MB (6279.59 MB after compression)
494186 165607     -206.6682   119      -51.0000     -367.2274 55535763  620.05%

GUB cover cuts applied:  1670
Clique cuts applied:  55
Cover cuts applied:  4658
Implied bound cuts applied:  117
Flow cuts applied:  184
Mixed integer rounding cuts applied:  4034
Zero-half cuts applied:  137
Lift and project cuts applied:  21
Gomory fractional cuts applied:  185

Root node processing (before b&c):
Real time             =    0.00 sec. (2.58 ticks)
Parallel b&c, 8 threads:
Real time             =  188.35 sec. (189207.47 ticks)
Sync time (average)   =    8.78 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) =  188.35 sec. (189210.06 ticks)

------------------------------
Iteration 14
Bounds on # of cuts = 8 with [3 3 2]
Error = 49 (out of 100 instances)
Accuracy = 51
Solving time = 3.139274398 min (minutes)
Accumulated time = 82.023340731 min (minutes)

Solution status code = 104
LB on error =  -267.006174534
Relative objective gap = 6.196199501

Selected variables:
```

```
A_AGE (Continuous)
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
------------------------------
Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File                      3
CPXPARAM_MIP_Limits_Solutions                   1
CPXPARAM_TimeLimit                              81478.599556152345
CPXPARAM_MIP_Limits_TreeMemory                  204800

Nodes                                         Cuts/
Node  Left     Objective  IInf  Best Integer    Best Bound    ItCnt     Gap

494456 182201    infeasible            -51.0000     -367.0062 56675674  619.62%
Elapsed time = 0.24 sec. (15.33 ticks, tree = 9524.00 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
494475 182210     -351.9932   224      -51.0000     -367.0062 56676084  619.62%
494530 182230     -312.2393   195      -51.0000     -367.0062 56676456  619.62%
494589 182255     -259.6874   171      -51.0000     -367.0062 56676687  619.62%
494665 182282     -180.5270   126      -51.0000     -367.0062 56676863  619.62%
494755 182309     -122.6764   100      -51.0000     -367.0062 56677062  619.62%
494863 182335        cutoff            -51.0000     -367.0062 56677152  619.62%
494937 182324      -78.8158    40      -51.0000     -367.0062 56678670  619.62%
494991 182280     -211.8674   166      -51.0000     -367.0062 56678002  619.62%
495064 182323      -88.9050    60      -51.0000     -367.0062 56678696  619.62%
495298 182342     -361.4826   400      -51.0000     -367.0062 56679876  619.62%
Elapsed time = 4.70 sec. (3143.89 ticks, tree = 9530.75 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
495594 182388     -251.8648   214      -51.0000     -367.0062 56683074  619.62%
495860 182577     -108.7543    80      -51.0000     -366.9523 56694950  619.51%
496088 182540     -189.7373   134      -51.0000     -366.9144 56684616  619.44%
496320 182525     -286.3870   178      -51.0000     -366.8762 56685783  619.37%
496537 182580     -340.4613   383      -51.0000     -366.8762 56706383  619.37%
496821 182691     -147.6478    81      -51.0000     -366.8762 56689431  619.37%
497372 182733      -88.9050    52      -51.0000     -366.8762 56690879  619.37%
497664 182720     -358.8124   331      -51.0000     -366.8762 56710686  619.37%
498118 182764     -237.3959   195      -51.0000     -366.8762 56719970  619.37%
498480 182825      -73.9050    56      -51.0000     -366.8762 56720555  619.37%
```

```
Elapsed time = 17.54 sec. (12704.97 ticks, tree = 9531.09 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
498995 182744      -91.4849   132      -51.0000     -366.8762 56695063  619.37%
499164 182989     -359.6095   298      -51.0000     -366.8762 56716539  619.37%
499601 182253     -244.0278   167      -51.0000     -366.8762 56701358  619.37%
500209 183036     -344.9522   226      -51.0000     -366.8762 56700971  619.37%
500569 183145        cutoff            -51.0000     -366.8762 56701706  619.37%
500875 183215     -223.8724   139      -51.0000     -366.8681 56703419  619.35%
501515 183296     -345.3847   265      -51.0000     -366.8681 56704825  619.35%
502158 182831      -92.9050    50      -51.0000     -366.8681 56713383  619.35%
502527 183166     -226.7766   170      -51.0000     -366.8681 56734624  619.35%
502909 182911     -262.1243   189      -51.0000     -366.8681 56716455  619.35%
Elapsed time = 31.50 sec. (22253.24 ticks, tree = 9560.30 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
503332 183801     -327.4005   260      -51.0000     -366.8681 56775885  619.35%
503678 183393      -63.9050    28      -51.0000     -366.8681 56750272  619.35%
503992 183427     -231.5535   138      -51.0000     -366.8681 56739737  619.35%
504587 183223      -69.9050    35      -51.0000     -366.8681 56721762  619.35%
504948 183535     -301.0740   190      -51.0000     -366.8681 56742532  619.35%
505495 184109     -189.3199   149      -51.0000     -366.8681 56735249  619.35%
505823 184172     -347.1391   255      -51.0000     -366.8681 56736378  619.35%
506089 184248     -152.5782    92      -51.0000     -366.8681 56737407  619.35%
506643 185098     -102.4718    45      -51.0000     -366.8681 56816717  619.35%
507163 183514      -94.8596    38      -51.0000     -366.8681 56762693  619.35%
Elapsed time = 46.09 sec. (31831.63 ticks, tree = 9612.19 MB, solutions = 37)
Nodefile size = 7507.91 MB (6546.68 MB after compression)
507847 183617     -150.3053    85      -51.0000     -366.8681 56764277  619.35%
508280 183802     -328.5517   206      -51.0000     -366.8681 56736660  619.35%
508940 182769     -294.7658   190      -51.0000     -366.8681 56727257  619.35%
509517 183778      -95.4761    51      -51.0000     -366.8681 56769219  619.35%
509986 183838     -290.1692   199      -51.0000     -366.8681 56771014  619.35%
510665 185497     -128.6918    82      -51.0000     -366.8681 56826754  619.35%
511065 184321     -310.4287   177      -51.0000     -366.8681 56758291  619.35%
511453 184748     -323.7543   217      -51.0000     -366.8681 56799934  619.35%
511733 185661     -352.0178   342      -51.0000     -366.8681 56831520  619.35%
512296 184878     -331.4491   218      -51.0000     -366.8681 56802445  619.35%
Elapsed time = 57.78 sec. (41390.10 ticks, tree = 9769.69 MB, solutions = 37)
Nodefile size = 7582.35 MB (6611.74 MB after compression)
512740 183738     -354.3047   315      -51.0000     -366.8681 56746494  619.35%
```

```
513064 183797     -218.5924   179      -51.0000     -366.8681 56747822  619.35%
513481 184788      -81.0717    42      -51.0000     -366.8681 56759505  619.35%
513901 185908      -76.0885    72      -51.0000     -366.8681 56837494  619.35%
514340 185153     -329.4190   291      -51.0000     -366.8681 56808466  619.35%
514728 186009     -167.6558   111      -51.0000     -366.8681 56840056  619.35%
515145 186083     -313.4338   183      -51.0000     -366.8681 56841160  619.35%
515566 186176     -351.2108   233      -51.0000     -366.8681 56842573  619.35%
516099 183458     -234.0999   156      -51.0000     -366.8681 56749879  619.35%
516357 184213     -145.4731    71      -51.0000     -366.8681 56758558  619.35%
Elapsed time = 70.16 sec. (50950.48 ticks, tree = 9712.96 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
516670 183638      -94.4050    69      -51.0000     -366.8681 56751485  619.35%
516864 185539     -353.3629   464      -51.0000     -366.8681 56816763  619.35%
517026 184475     -139.9466    79      -51.0000     -366.8681 56762655  619.35%
517314 183765     -107.6787    60      -51.0000     -366.8681 56756087  619.35%
517555 183845     -229.9116   137      -51.0000     -366.8681 56757069  619.35%
517758 185685     -338.3882   320      -51.0000     -366.8681 56822383  619.35%
517891 186354     -219.8397   132      -51.0000     -366.8681 56852885  619.35%
518073 184508     -358.8005   571      -51.0000     -366.8681 56769302  619.35%
518144 186464     -294.3353   217      -51.0000     -366.8681 56855343  619.35%
518452 184522     -338.0686   327      -51.0000     -366.8681 56773560  619.35%
Elapsed time = 82.11 sec. (60586.41 ticks, tree = 9748.86 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
518550 186598     -301.8589   186      -51.0000     -366.8681 56857731  619.35%
518811 184586     -223.8810   142      -51.0000     -366.8681 56777456  619.35%
519155 186711     -339.9077   213      -51.0000     -366.8681 56860244  619.35%
519520 184342     -334.0798   215      -51.0000     -366.8681 56774326  619.35%
520022 184788     -364.9442   404      -51.0000     -366.8681 56781028  619.35%
520231 184896     -112.3531    60      -51.0000     -366.8681 56782057  619.35%
520511 186342      -61.9044    48      -51.0000     -366.8681 56836938  619.35%
520730 185006     -324.4910   234      -51.0000     -366.8681 56821850  619.35%
521264 186394     -278.5470   174      -51.0000     -366.8681 56840495  619.35%
521704 187004    infeasible            -51.0000     -366.8681 56869988  619.35%
Elapsed time = 94.06 sec. (70165.35 ticks, tree = 10016.79 MB, solutions = 37)
Nodefile size = 7722.86 MB (6734.35 MB after compression)
522368 185197     -202.6451   126      -51.0000     -366.8681 56827042  619.35%
523238 186645     -324.7403   228      -51.0000     -366.8681 56843991  619.35%
523980 184871     -232.7469   163      -51.0000     -366.8681 56807304  619.35%
524708 185358     -157.1693   125      -51.0000     -366.8681 56831143  619.35%
```

```
525280 185365     -269.3653   153      -51.0000     -366.8681 56795954  619.35%
526076 187442     -206.7137   130      -51.0000     -366.8681 56875020  619.35%
526790 187097     -172.2746    99      -51.0000     -366.8681 56849651  619.35%
527291 187608     -120.3658    68      -51.0000     -366.8681 56877135  619.35%
527767 187253     -100.7237    59      -51.0000     -366.8681 56851707  619.35%
528154 185854     -221.2637   143      -51.0000     -366.8681 56837647  619.35%
Elapsed time = 105.04 sec. (79721.78 ticks, tree = 9885.67 MB, solutions = 37)
Nodefile size = 7507.91 MB (6546.68 MB after compression)
528448 185109     -360.5449   304      -51.0000     -366.8681 56798386  619.35%
528973 187895      -53.9050    24      -51.0000     -366.8681 56882736  619.35%
529424 187460     -214.0870   144      -51.0000     -366.8681 56857690  619.35%
529852 185284     -258.7113   179      -51.0000     -366.8681 56801753  619.35%
530303 185125     -310.7185   195      -51.0000     -366.8681 56801060  619.35%
530717 186242     -282.9556   190      -51.0000     -366.8681 56845048  619.35%
531229 188181     -355.5929   249      -51.0000     -366.8681 56888841  619.35%
531749 185561     -244.8323   151      -51.0000     -366.8681 56806389  619.35%
532217 187856     -154.1270   103      -51.0000     -366.8681 56865472  619.35%
534491 186745     -336.7932   237      -51.0000     -366.8681 56853455  619.35%
Elapsed time = 119.93 sec. (92134.22 ticks, tree = 9989.67 MB, solutions = 37)
Nodefile size = 7507.91 MB (6546.68 MB after compression)
537173 186121      -92.9050    64      -51.0000     -366.8681 56817216  619.35%
539433 186104     -360.0615   320      -51.0000     -366.8681 56829949  619.35%
541783 189363     -350.7550   227      -51.0000     -366.8681 56911498  619.35%
544525 189732     -354.4750   399      -51.0000     -366.8681 56916526  619.35%
547325 187207     -180.8447   112      -51.0000     -366.8681 56852153  619.35%
549534 187269     -359.7960   299      -51.0000     -366.8681 56841886  619.35%
552483 188561      -76.0000    37      -51.0000     -366.8681 56890908  619.35%
555018 187941     -292.0210   169      -51.0000     -366.8681 56850235  619.35%
557686 188231     -248.4755   165      -51.0000     -366.8681 56855537  619.35%
560583 190787     -328.4668   210      -51.0000     -366.8681 56924690  619.35%
Elapsed time = 165.90 sec. (130289.67 ticks, tree = 10459.45 MB, solutions = 37)
Nodefile size = 7582.35 MB (6611.74 MB after compression)
563125 189628      -59.9050    34      -51.0000     -366.8681 56911187  619.35%
565396 189136     -263.8448   164      -51.0000     -366.8681 56885160  619.35%
568071 190242     -138.8590    81      -51.0000     -366.8209 56920270  619.26%
570320 189734     -104.5327    70      -51.0000     -366.8209 56893599  619.26%
573161 191852     -256.3504   179      -51.0000     -366.8209 57017459  619.26%
575843 191145     -210.8755   128      -51.0000     -366.8209 56934904  619.26%
578475 190142     -345.4650   248      -51.0000     -366.8209 56896990  619.26%
```

```
581192 192533    -166.7373    98      -51.0000     -366.8209 57036295  619.26%
583459 192174    -248.0752   140      -51.0000     -366.8209 56949279  619.26%
585497 192912    -207.3005   124      -51.0000     -366.8209 57048453  619.26%
Elapsed time = 227.81 sec. (168444.95 ticks, tree = 10705.98 MB, solutions = 37)
Nodefile size = 8470.98 MB (7389.34 MB after compression)
587923 194446    -219.1194   128      -51.0000     -366.8209 57002407  619.26%
590344 193814    -191.1955   108      -51.0000     -366.8209 56985418  619.26%
592510 191113    -132.6357    88      -51.0000     -366.8209 56935710  619.26%
594613 193928    -278.0600   157      -51.0000     -366.8209 57069018  619.26%
596034 194250    -121.5324    72      -51.0000     -366.8209 57074094  619.26%
597396 191764    -298.5444   188      -51.0000     -366.8209 56955753  619.26%
598784 192141    -156.6665    97      -51.0000     -366.8209 56955666  619.26%
599769 192343    -327.9550   264      -51.0000     -366.8209 56962010  619.26%
600940 192582     -61.4004    30      -51.0000     -366.8209 56968128  619.26%
602947 191282    -360.3925   339      -51.0000     -366.8209 56966375  619.26%
Elapsed time = 273.41 sec. (206606.47 ticks, tree = 10538.83 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)
604824 195159    -209.5223   165      -51.0000     -366.8209 57110082  619.26%
606991 194686    -228.1652   141      -51.0000     -366.8209 57033764  619.26%
609377 196058     -89.4794    40      -51.0000     -366.8209 57072395  619.26%
611483 196054    -210.2735   128      -51.0000     -366.8209 57126646  619.26%
612145 196417    -241.6389   147      -51.0000     -366.8209 57130810  619.26%
612256 195015    -359.0492  1034      -51.0000     -366.8125 57046859  619.24%
612368 217470    -320.2838   211      -51.0000     -366.7797 57738968  619.18%
612887 228501    -284.2145   276      -51.0000     -366.7797 58010282  619.18%
613500 239780    -358.5293   274      -51.0000     -366.7797 58330379  619.18%
613861 251538    -360.7471   397      -51.0000     -366.7514 58625105  619.12%
Elapsed time = 387.78 sec. (245504.90 ticks, tree = 17529.07 MB, solutions = 37)
Nodefile size = 15466.73 MB (13518.12 MB after compression)
615353 239610    -359.5604  1040      -51.0000     -366.7514 58326157  619.12%
616586 263789    -273.0794   174      -51.0000     -366.7514 58939204  619.12%
617658 274839    -355.0167   266      -51.0000     -366.3450 59284748  618.32%
618974 275150    -281.4216   230      -51.0000     -366.3450 59302104  618.32%
620336 276782    -209.2482   130      -51.0000     -366.3450 59362700  618.32%
621684 277961    -214.6874   119      -51.0000     -366.3450 59441273  618.32%
622900 278715    -298.6923   213      -51.0000     -366.3450 59465451  618.32%
624291 279922    -315.4854   231      -51.0000     -366.3450 59533597  618.32%
625218 281037    -120.8353    63      -51.0000     -366.3450 59570495  618.32%
625993 281792    -361.4253   347      -51.0000     -366.3450 59617364  618.32%
```

```
Elapsed time = 469.11 sec. (283897.44 ticks, tree = 21071.25 MB, solutions = 37)
Nodefile size = 18993.43 MB (16609.64 MB after compression)
626629 282086     -355.1436   393      -51.0000     -366.3450 59634771  618.32%
627551 282737     -161.8955   100      -51.0000     -366.3450 59683802  618.32%
628412 283151     -358.0560   333      -51.0000     -366.3450 59702143  618.32%
629606 283908     -223.1311   128      -51.0000     -366.3358 59768358  618.31%
630987 285351     -186.6854   131      -51.0000     -365.9983 59853631  617.64%
631970 286256      -60.4004    37      -51.0000     -365.9983 59881553  617.64%
632808 286815     -190.7839   136      -51.0000     -365.9983 59919228  617.64%
634294 287409     -119.7052    96      -51.0000     -365.9983 59983074  617.64%
635715 288834     -355.2322   320      -51.0000     -365.8797 60038286  617.41%
636500 289526     -336.6266   237      -51.0000     -365.8797 60093169  617.41%
Elapsed time = 527.49 sec. (322134.89 ticks, tree = 22006.45 MB, solutions = 37)
Nodefile size = 19922.83 MB (17427.82 MB after compression)
637899 289868     -261.2537   170      -51.0000     -365.8532 60117036  617.36%
639303 291156     -357.4336   362      -51.0000     -365.8468 60164756  617.35%
640364 292296     -357.0002   225      -51.0000     -365.8468 60205310  617.35%
641826 293296     -129.2980    67      -51.0000     -365.8468 60231289  617.35%
643710 294344     -324.7103   219      -51.0000     -365.8468 60275209  617.35%
645087 295929     -357.5296   251      -51.0000     -365.8468 60347341  617.35%
647574 297096     -361.3072   347      -51.0000     -365.8468 60403205  617.35%
650132 298525     -157.9824    91      -51.0000     -365.8468 60437070  617.35%
652370 300285     -215.2495   130      -51.0000     -365.8468 60481233  617.35%
653642 302565     -225.2487   127      -51.0000     -365.8468 60540176  617.35%
Elapsed time = 588.75 sec. (360318.24 ticks, tree = 23214.25 MB, solutions = 37)
Nodefile size = 21147.62 MB (18482.80 MB after compression)
655359 303578     -241.1639   143      -51.0000     -365.8468 60576128  617.35%
656778 304539     -233.3815   133      -51.0000     -365.7387 60611664  617.13%
658460 305910     -334.7923   278      -51.0000     -365.6873 60683628  617.03%
661036 307178     -306.5428   187      -51.0000     -365.6873 60721530  617.03%
662791 308542     -360.1018   349      -51.0000     -365.6873 60767056  617.03%
664931 310615      -73.4004    33      -51.0000     -365.6873 60843282  617.03%
666181 311479      -80.9050    38      -51.0000     -365.5489 60873920  616.76%
667712 313460     -341.7799   221      -51.0000     -365.4342 60942375  616.54%
668738 314033     -250.3615   164      -51.0000     -365.4342 60969439  616.54%
670378 314777     -340.3181   254      -51.0000     -365.4342 61007417  616.54%
Elapsed time = 648.51 sec. (398512.68 ticks, tree = 24220.43 MB, solutions = 37)
Nodefile size = 22149.07 MB (19347.63 MB after compression)
671660 316624     -190.6028   117      -51.0000     -365.4342 61082628  616.54%
```

```
673339 316740    -255.8649   201     -51.0000    -365.4342 61117104  616.54%
675296 318619    -119.2922    64     -51.0000    -365.4342 61162844  616.54%
677401 320444    -231.1208   167     -51.0000    -365.4342 61223447  616.54%
679864 321923    -307.6958   207     -51.0000    -365.4342 61254347  616.54%
681222 323429    -355.7521   293     -51.0000    -365.4342 61293481  616.54%
682604 324985    -164.2641    90     -51.0000    -365.3694 61405616  616.41%
684015 325743    -179.6358   117     -51.0000    -365.3555 61458609  616.38%
685518 327413    -250.6560   141     -51.0000    -365.3071 61539485  616.29%
687434 328626    -146.6897    95     -51.0000    -365.3062 61584384  616.29%
Elapsed time = 708.04 sec. (436685.01 ticks, tree = 25451.98 MB, solutions = 37)
Nodefile size = 23372.09 MB (20413.94 MB after compression)
689399 329467     -99.3480    36     -51.0000    -365.2479 61635355  616.17%
691000 331344    -346.8231   238     -51.0000    -365.2050 61692904  616.09%
692237 332230    -329.2119   241     -51.0000    -365.2050 61733192  616.09%
693523 332898     -86.5479    42     -51.0000    -365.2050 61759830  616.09%
694552 333849    -187.8206   113     -51.0000    -365.1849 61826192  616.05%
696545 334946     -64.0000    28     -51.0000    -365.1849 61889587  616.05%
698225 336435    -223.7746   142     -51.0000    -365.1395 61969519  615.96%
700385 337181    -141.2558    76     -51.0000    -365.1393 61999411  615.96%
701942 339213    -228.3630   129     -51.0000    -365.1151 62061295  615.91%
703039 340138    -336.6943   518     -51.0000    -365.1074 62106040  615.90%
Elapsed time = 769.48 sec. (474868.46 ticks, tree = 26523.33 MB, solutions = 37)
Nodefile size = 24455.97 MB (21345.49 MB after compression)
703806 340972    -154.5474    96     -51.0000    -365.1074 62151674  615.90%
704648 342280    -338.7462   252     -51.0000    -365.1031 62231946  615.89%
705803 342510    -349.4838   328     -51.0000    -365.0948 62264654  615.87%
706909 343736    -348.7916   269     -51.0000    -365.0948 62339333  615.87%
708639 344121    -208.9617   132     -51.0000    -365.0948 62361186  615.87%
710029 345547    -179.6985   112     -51.0000    -365.0948 62447113  615.87%
711771 346626    -185.8141   108     -51.0000    -365.0912 62486059  615.87%
712627 348066    -362.4201   343     -51.0000    -365.0912 62582067  615.87%
713715 348780     -80.0606    43     -51.0000    -365.0912 62624224  615.87%
715391 349314    -306.6991   235     -51.0000    -365.0912 62666144  615.87%
Elapsed time = 824.55 sec. (513173.77 ticks, tree = 26881.08 MB, solutions = 37)
Nodefile size = 24808.87 MB (21640.42 MB after compression)
717378 350702    -353.4336   324     -51.0000    -365.0912 62715620  615.87%
719540 351649    -316.9172   222     -51.0000    -365.0912 62746033  615.87%
721322 353579    -162.3109    86     -51.0000    -365.0912 62799262  615.87%
723113 355134     -63.9143    35     -51.0000    -365.0289 62843640  615.74%
```

```
724802 356270     -143.9895    81      -51.0000     -365.0169 62884338  615.72%
726441 357146     -175.7427   100      -51.0000     -365.0169 62911220  615.72%
728427 358874     -343.8456   331      -51.0000     -365.0169 63006867  615.72%
731003 361195     -342.7434   262      -51.0000     -365.0169 63074158  615.72%
733427 361941     -268.4267   171      -51.0000     -364.9677 63090909  615.62%
735290 363459        cutoff            -51.0000     -364.9677 63130298  615.62%
Elapsed time = 885.78 sec. (551330.14 ticks, tree = 28246.52 MB, solutions = 37)
Nodefile size = 26162.99 MB (22819.78 MB after compression)
737115 365594     -144.9050    89      -51.0000     -364.9635 63178021  615.61%
738541 366505     -117.0880    69      -51.0000     -364.9446 63192669  615.58%
739326 367895     -338.1909   310      -51.0000     -364.9446 63273313  615.58%
740151 368444     -354.4144   323      -51.0000     -364.9446 63300507  615.58%
742291 369430     -258.6669   164      -51.0000     -364.9336 63409029  615.56%
745357 370124     -133.1314    67      -51.0000     -364.9268 63420455  615.54%
747378 373306      -70.4004    24      -51.0000     -364.9221 63486694  615.53%
749580 374547      -60.0000    43      -51.0000     -364.9158 63533026  615.52%
752396 376503     -224.8379   132      -51.0000     -364.9158 63590702  615.52%
753817 377198     -110.4004    59      -51.0000     -364.9158 63601596  615.52%
Elapsed time = 947.27 sec. (589510.67 ticks, tree = 29838.63 MB, solutions = 37)
Nodefile size = 27723.94 MB (24182.95 MB after compression)
754664 378350     -313.3719   241      -51.0000     -364.9158 63637522  615.52%
755945 380009     -132.6635    77      -51.0000     -364.8896 63692159  615.47%
756996 381032     -114.4004    55      -51.0000     -364.8721 63750087  615.44%
758046 382017     -353.4691   330      -51.0000     -364.8721 63794359  615.44%
758657 382456     -354.2886   246      -51.0000     -364.8721 63843088  615.44%
759881 382519     -240.3827   153      -51.0000     -364.8710 63859500  615.43%
761113 384017     -109.7342    57      -51.0000     -364.8710 63946364  615.43%
762231 384489     -201.7776   137      -51.0000     -364.8699 63967543  615.43%
763687 385146     -167.7341    97      -51.0000     -364.8699 64005961  615.43%
764990 386464     -360.0574   326      -51.0000     -364.8699 64058084  615.43%
Elapsed time = 1005.19 sec. (627814.24 ticks, tree = 30794.27 MB, solutions = 37)
Nodefile size = 28692.51 MB (25023.74 MB after compression)
765714 386900     -139.3959    80      -51.0000     -364.8697 64109034  615.43%
766817 387531     -295.4339   190      -51.0000     -364.8697 64159777  615.43%
767913 388740      -70.4004    29      -51.0000     -364.8697 64211795  615.43%
768975 390150     -137.9050    71      -51.0000     -364.8697 64307062  615.43%
771045 390586     -353.6152   274      -51.0000     -364.8488 64348089  615.39%
773557 392244      -62.7203    32      -51.0000     -364.8292 64409874  615.35%
775988 394237        cutoff            -51.0000     -364.8095 64462634  615.31%
```

```
777702 396139     -166.8143    88       -51.0000     -364.8095 64503623  615.31%
779614 396520     -122.6436    68       -51.0000     -364.7910 64539613  615.28%
782146 398855     -312.5603   192       -51.0000     -364.7910 64610935  615.28%
Elapsed time = 1065.82 sec. (665982.42 ticks, tree = 32000.35 MB, solutions = 37)
Nodefile size = 29928.83 MB (26098.76 MB after compression)
784000 399838     -224.3325   136       -51.0000     -364.7910 64651290  615.28%
785883 401786     -194.0282   115       -51.0000     -364.7910 64740881  615.28%
787276 402494     -236.2952   187       -51.0000     -364.7910 64773173  615.28%
788203 403332     -208.3501   132       -51.0000     -364.7626 64821019  615.22%
789654 404080     -274.5377   173       -51.0000     -364.7626 64871019  615.22%
791185 405717     -136.7522    74       -51.0000     -364.7626 64928476  615.22%
792944 407063     -143.8552    81       -51.0000     -364.7489 65009012  615.19%
794449 407935      -60.4004    35       -51.0000     -364.7489 65055525  615.19%
796012 408937     -244.0269   148       -51.0000     -364.7489 65090206  615.19%
797658 410676     -108.4004    65       -51.0000     -364.7316 65157440  615.16%
Elapsed time = 1123.50 sec. (704203.36 ticks, tree = 32906.29 MB, solutions = 37)
Nodefile size = 30835.32 MB (26886.41 MB after compression)
799447 411601     -334.4220   270       -51.0000     -364.7302 65214712  615.16%
800825 412665     -327.5934   259       -51.0000     -364.7141 65259056  615.13%
801941 413971     -339.3653   241       -51.0000     -364.7058 65332119  615.11%
803933 414717      -68.2934    28       -51.0000     -364.7058 65352630  615.11%
806553 416163     -182.9371   105       -51.0000     -364.7058 65420516  615.11%
808329 417827      -92.0000    46       -51.0000     -364.6968 65446803  615.09%
809926 419512     -324.4454   225       -51.0000     -364.6968 65503730  615.09%
811015 420726     -346.9501   222       -51.0000     -364.6855 65546728  615.07%
812351 421285     -332.8297   220       -51.0000     -364.6809 65576229  615.06%
813635 422486     -188.0082   108       -51.0000     -364.6809 65605887  615.06%
Elapsed time = 1183.30 sec. (742384.03 ticks, tree = 34000.77 MB, solutions = 37)
Nodefile size = 31911.50 MB (27825.65 MB after compression)
815552 423494      -73.9775    32       -51.0000     -364.6777 65663571  615.05%
817134 424794     -341.0814   263       -51.0000     -364.6777 65690837  615.05%
818641 426281     -180.3990   110       -51.0000     -364.6777 65757727  615.05%
820682 426974     -165.8716    91       -51.0000     -364.6777 65800359  615.05%
822833 428289      -84.4004    53       -51.0000     -364.6777 65824189  615.05%
824603 430176     -322.1515   209       -51.0000     -364.6777 65871864  615.05%
826717 432281     -222.8604   118       -51.0000     -364.6777 65938161  615.05%
828986 432669     -221.0570   168       -51.0000     -364.6777 65943629  615.05%
830980 435000     -274.5929   162       -51.0000     -364.6777 66001113  615.05%
833801 436907     -324.0902   213       -51.0000     -364.6475 66128348  615.00%
```

```
Elapsed time = 1245.90 sec. (780552.64 ticks, tree = 35882.93 MB, solutions = 37)
Nodefile size = 33776.48 MB (29467.99 MB after compression)
835709 439181     -133.2156    72       -51.0000     -364.6475 66178885  615.00%
837674 439908     -175.4624   114       -51.0000     -364.6475 66189714  615.00%
839601 441162     -250.9862   176       -51.0000     -364.6475 66240455  615.00%
841355 442464     -300.2932   199       -51.0000     -364.5726 66291801  614.85%
842695 444227     -317.4591   246       -51.0000     -364.5726 66361667  614.85%
844185 445795     -174.4656    98       -51.0000     -364.5726 66440393  614.85%
845686 446846     -285.6416   179       -51.0000     -364.5718 66500594  614.85%
847592 448069     -114.7342    59       -51.0000     -364.5542 66550404  614.81%
849312 448835     -257.9658   167       -51.0000     -364.5542 66582371  614.81%
851394 450013     -314.9399   211       -51.0000     -364.5542 66633782  614.81%
Elapsed time = 1307.35 sec. (818726.26 ticks, tree = 37244.89 MB, solutions = 37)
Nodefile size = 35133.82 MB (30656.34 MB after compression)
853084 452324     -312.0660   196       -51.0000     -364.5542 66693652  614.81%
854812 453846     -356.9786   261       -51.0000     -364.5542 66761242  614.81%
855968 454651      -63.4004    24       -51.0000     -364.5542 66802143  614.81%
857129 455667     -171.9293    96       -51.0000     -364.5490 66843806  614.80%
858381 456135     -163.1172    96       -51.0000     -364.5490 66892873  614.80%
860461 456922      -61.1046    29       -51.0000     -364.5490 66953083  614.80%
862972 458277     -214.0353   124       -51.0000     -364.5200 66982830  614.75%
865304 460473     -180.0223   111       -51.0000     -364.5200 67059361  614.75%
867660 461169     -321.5716   208       -51.0000     -364.4985 67072536  614.70%
870293 463316     -340.5852   217       -51.0000     -364.4819 67128946  614.67%
Elapsed time = 1368.78 sec. (856888.40 ticks, tree = 38648.48 MB, solutions = 37)
Nodefile size = 36539.17 MB (31877.98 MB after compression)
873538 467608     -217.7467   139       -51.0000     -364.4664 67233746  614.64%
876593 467125     -244.4728   135       -51.0000     -364.4574 67228464  614.62%
879178 470882     -154.9824   104       -51.0000     -364.4499 67296718  614.61%
881958 472445     -284.8297   214       -51.0000     -364.4351 67334944  614.58%
884732 474861     -279.1491   156       -51.0000     -364.4351 67377191  614.58%
887617 477416     -315.0698   194       -51.0000     -364.4211 67435378  614.55%
890379 478124     -214.2439   123       -51.0000     -364.4195 67448458  614.55%
892245 480785     -325.1725   248       -51.0000     -364.4066 67510545  614.52%
894557 482750     -324.9394   205       -51.0000     -364.4066 67569546  614.52%
896840 483406     -343.9195   287       -51.0000     -364.3964 67595487  614.50%
Elapsed time = 1434.42 sec. (895055.27 ticks, tree = 41047.78 MB, solutions = 37)
Nodefile size = 38972.02 MB (34000.81 MB after compression)
898846 485804     -362.7281   405       -51.0000     -364.3964 67685395  614.50%
```

```
900772 486739     -93.3809    45      -51.0000     -364.3964 67709447  614.50%
902306 488326    -249.0641   223      -51.0000     -364.3780 67756185  614.47%
904443 489887    -182.8472   107      -51.0000     -364.3780 67817292  614.47%
906206 491028    -234.4828   133      -51.0000     -364.3780 67848657  614.47%
907466 491892    -312.0740   182      -51.0000     -364.3676 67899357  614.45%
908931 493915    -326.9604   233      -51.0000     -364.3676 67959190  614.45%
910191 494806    -275.8860   191      -51.0000     -364.3676 68017211  614.45%
911432 496455     -70.3965    32      -51.0000     -364.3676 68085484  614.45%
912334 496717     -64.4004    28      -51.0000     -364.3676 68095822  614.45%
Elapsed time = 1492.98 sec. (933225.40 ticks, tree = 41910.78 MB, solutions = 37)
Nodefile size = 39834.84 MB (34729.80 MB after compression)
913439 497838    -194.3815   105      -51.0000     -364.3676 68177102  614.45%
914980 498261    -152.9293    86      -51.0000     -364.3676 68196338  614.45%
915804 499766    -323.8244   224      -51.0000     -364.3575 68290289  614.43%
916628 500079    -302.3960   211      -51.0000     -364.3575 68305529  614.43%
918039 500368    -343.3726   228      -51.0000     -364.3403 68340234  614.39%
920007 501929    -275.8006   198      -51.0000     -364.3317 68419509  614.38%
922741 503623    -362.6283   406      -51.0000     -364.3275 68467641  614.37%
925606 505643    -142.1086    79      -51.0000     -364.3179 68521503  614.35%
928546 508163    -217.8474   137      -51.0000     -364.3103 68580599  614.33%
930886 509848    -158.5826    87      -51.0000     -364.2995 68622180  614.31%
Elapsed time = 1554.53 sec. (971382.80 ticks, tree = 43251.15 MB, solutions = 37)
Nodefile size = 41149.86 MB (35884.09 MB after compression)
932899 511986    -119.3072    74      -51.0000     -364.2902 68685278  614.29%
934637 512936    -269.4526   187      -51.0000     -364.2902 68703163  614.29%
936749 513505    -198.9682   162      -51.0000     -364.2805 68733415  614.28%
939019 516384    -100.4004    61      -51.0000     -364.2805 68830529  614.28%
940965 516910    -213.4897   124      -51.0000     -364.2729 68840204  614.26%
943366 518019    -329.1310   247      -51.0000     -364.2674 68885751  614.25%
946119 520442    -350.7558   252      -51.0000     -364.2625 68944343  614.24%
949262 523916    -170.8749    94      -51.0000     -364.2478 69045300  614.21%
951577 525662    -284.4097   170      -51.0000     -364.2457 69087488  614.21%
953822 526036    -343.7839   272      -51.0000     -364.2457 69097886  614.21%
Elapsed time = 1618.93 sec. (1009540.36 ticks, tree = 44976.81 MB, solutions = 37)
Nodefile size = 42900.58 MB (37403.42 MB after compression)
956067 528253    -114.9327    57      -51.0000     -364.2457 69141165  614.21%
958128 529673    -203.9004   114      -51.0000     -364.2349 69171360  614.19%
960075 531911     -80.4004    39      -51.0000     -364.2178 69250399  614.15%
961383 532901    -192.4865   122      -51.0000     -364.2178 69269827  614.15%
```

```
963351 534290     -331.6833   237      -51.0000     -364.2171 69334703  614.15%
964998 535026     -292.4749   209      -51.0000     -364.2171 69368474  614.15%
966596 537588     -233.1557   129      -51.0000     -364.2171 69455104  614.15%
968783 537908    infeasible            -51.0000     -364.1968 69462106  614.11%
970664 538749     -158.7677    91      -51.0000     -364.1944 69525096  614.11%
971877 540717     -303.3489   187      -51.0000     -364.1830 69565557  614.08%
Elapsed time = 1681.97 sec. (1047705.63 ticks, tree = 46825.36 MB, solutions = 37)
Nodefile size = 44749.88 MB (39030.34 MB after compression)
972591 541449     -360.6409   389      -51.0000     -364.1830 69614316  614.08%
973284 542393     -346.1220   219      -51.0000     -364.1810 69668081  614.08%
974504 543255     -356.6271   308      -51.0000     -364.1748 69742147  614.07%
975615 544122      -82.3339    49      -51.0000     -364.1721 69809177  614.06%
976405 544162     -359.4143   328      -51.0000     -364.1721 69815975  614.06%
978363 545748     -101.4004    57      -51.0000     -364.1668 69906213  614.05%
979846 546197     -351.0579   406      -51.0000     -364.1654 69950306  614.05%
981386 547870      -81.4004    39      -51.0000     -364.1654 69980541  614.05%
982550 549015     -333.7721   202      -51.0000     -364.1654 70056096  614.05%
983567 549656     -147.8308    79      -51.0000     -364.1654 70073713  614.05%
Elapsed time = 1742.23 sec. (1085912.50 ticks, tree = 47716.70 MB, solutions = 37)
Nodefile size = 45612.43 MB (39779.51 MB after compression)
984554 551413         cutoff           -51.0000     -364.1654 70161318  614.05%
985491 551428     -150.5823    93      -51.0000     -364.1654 70191726  614.05%
986750 552700     -282.6257   188      -51.0000     -364.1467 70255403  614.01%
988694 553598     -362.4581   443      -51.0000     -364.1387 70317096  614.00%
990679 555384     -217.3788   127      -51.0000     -364.1311 70394011  613.98%
992846 556974     -362.6461   391      -51.0000     -364.1311 70465635  613.98%
994875 556704     -249.0947   144      -51.0000     -364.1311 70449904  613.98%
996495 558587      -56.8487    28      -51.0000     -364.1193 70519524  613.96%
998699 558897      -98.4589    53      -51.0000     -364.1120 70551356  613.95%
1000118 561480     -343.5201   231      -51.0000     -364.1120 70621249  613.95%
Elapsed time = 1798.66 sec. (1124089.14 ticks, tree = 48342.35 MB, solutions = 37)
Nodefile size = 46248.91 MB (40321.99 MB after compression)
1002022 563411     -277.8063   195      -51.0000     -364.1120 70676416  613.95%
1003930 564748      -65.4004    19      -51.0000     -364.1120 70710284  613.95%
1006162 565013     -362.5691   336      -51.0000     -364.1120 70739515  613.95%
1008681 566024     -125.8004    73      -51.0000     -364.1120 70757009  613.95%
1010748 569646      -67.4004    33      -51.0000     -364.1120 70829790  613.95%
1012267 569841     -291.9516   204      -51.0000     -364.1120 70837248  613.95%
1013891 572086     -161.2518    85      -51.0000     -364.1120 70909039  613.95%
```

```
1015221 573589     -211.6472   122      -51.0000     -364.1120 70967323  613.95%
1016223 573677     -312.2773   198      -51.0000     -364.1120 70974601  613.95%
1018064 575321      -64.4004    27      -51.0000     -364.0706 71125303  613.86%
Elapsed time = 1860.88 sec. (1162268.08 ticks, tree = 49744.02 MB, solutions = 37)
Nodefile size = 47631.36 MB (41523.58 MB after compression)
1019166 576465     -115.9403    63      -51.0000     -364.0706 71178541  613.86%
1020846 576679      -64.4004    35      -51.0000     -364.0568 71195308  613.84%
1022213 578055     -173.5622    90      -51.0000     -364.0568 71266779  613.84%
1023857 578647      -65.4004    29      -51.0000     -364.0531 71297045  613.83%
1026303 581678     -234.5717   164      -51.0000     -364.0414 71391239  613.81%
1029153 583567     -158.5802    93      -51.0000     -364.0414 71445861  613.81%
1032346 585534     -348.8949   248      -51.0000     -364.0236 71475979  613.77%
1035328 585926     -347.8431   215      -51.0000     -364.0196 71480905  613.76%
1037744 587920     -211.7419   131      -51.0000     -364.0029 71521216  613.73%
1040441 591033     -303.7881   176      -51.0000     -363.9979 71589175  613.72%
Elapsed time = 1926.76 sec. (1200428.91 ticks, tree = 51781.74 MB, solutions = 37)
Nodefile size = 49671.30 MB (43311.39 MB after compression)
1042352 593264      -71.9796    30      -51.0000     -363.9963 71626550  613.72%
1043678 593042     -324.0286   219      -51.0000     -363.9963 71627371  613.72%
1045587 595732     -200.1915   114      -51.0000     -363.9832 71708209  613.69%
1047688 596461     -254.6115   163      -51.0000     -363.9832 71730582  613.69%
1049872 597740     -287.0454   175      -51.0000     -363.9832 71785578  613.69%
1051704 600386      -91.4004    47      -51.0000     -363.9832 71849627  613.69%
1053617 602054     -261.5171   153      -51.0000     -363.9772 71927071  613.68%
1055976 603674     -132.4849    72      -51.0000     -363.9772 71965461  613.68%
1058607 604897     -255.3902   153      -51.0000     -363.9635 72011301  613.65%
1060413 605986     -354.7212   330      -51.0000     -363.9578 72031929  613.64%
Elapsed time = 1988.67 sec. (1238609.25 ticks, tree = 53778.28 MB, solutions = 37)
Nodefile size = 51644.80 MB (45060.90 MB after compression)
1061914 607317        cutoff            -51.0000     -363.9507 72074436  613.63%
1063680 609340     -360.3288   326      -51.0000     -363.9390 72148771  613.61%
1065328 610155     -124.4046    63      -51.0000     -363.9390 72161179  613.61%
1066797 611383      -59.0000    29      -51.0000     -363.9390 72237860  613.61%
1068142 612237     -224.3689   137      -51.0000     -363.9354 72271213  613.60%
1070142 614705      -76.4004    67      -51.0000     -363.9267 72406469  613.58%
1071992 614979     -246.9402   155      -51.0000     -363.9267 72398235  613.58%
1073903 617010     -228.2843   137      -51.0000     -363.9267 72494327  613.58%
1075706 617392     -204.5836   114      -51.0000     -363.9267 72507148  613.58%
1077501 619338      -86.0025    40      -51.0000     -363.9267 72547889  613.58%
```

```
Elapsed time = 2046.66 sec. (1276770.39 ticks, tree = 54677.74 MB, solutions = 37)
Nodefile size = 52565.31 MB (45853.57 MB after compression)
1079161 620410     -209.3248   118      -51.0000     -363.9135 72608861   613.56%
1081649 622851     -300.1106   181      -51.0000     -363.8983 72686256   613.53%
1083926 623234     -323.1341   202      -51.0000     -363.8983 72691650   613.53%
1086076 625246     -193.9602   117      -51.0000     -363.8939 72732098   613.52%
1088179 627756     -283.5262   204      -51.0000     -363.8939 72790211   613.52%
1091190 628092     -287.6054   202      -51.0000     -363.8939 72814198   613.52%
1093431 629524     -254.8223   146      -51.0000     -363.8939 72854966   613.52%
1095986 632197     -346.0530   225      -51.0000     -363.8939 72931006   613.52%
1098500 634277     -179.1473   104      -51.0000     -363.8939 72978948   613.52%
1100539 636794     -187.8855   109      -51.0000     -363.8939 73044618   613.52%
Elapsed time = 2112.64 sec. (1314938.67 ticks, tree = 56546.65 MB, solutions = 37)
Nodefile size = 54466.62 MB (47506.30 MB after compression)
1103600 637668     -312.4463   201      -51.0000     -363.8939 73072583   613.52%
1106082 638900     -267.2381   173      -51.0000     -363.8939 73105694   613.52%
1108007 641241     -209.4077   120      -51.0000     -363.8939 73190173   613.52%
1109950 644769      -99.5139    51      -51.0000     -363.8939 73272081   613.52%
1111945 645280      -92.0000    48      -51.0000     -363.8939 73287605   613.52%
1113936 646411     -228.3004   131      -51.0000     -363.8939 73319493   613.52%
1116470 648988     -229.0410   145      -51.0000     -363.8939 73413311   613.52%
1119248 649821     -191.2266   109      -51.0000     -363.8939 73426213   613.52%
1121744 651852     -229.0925   141      -51.0000     -363.8939 73474305   613.52%
1124550 652993     -117.5139    51      -51.0000     -363.8939 73494935   613.52%
Elapsed time = 2177.62 sec. (1353097.69 ticks, tree = 58255.81 MB, solutions = 37)
Nodefile size = 56118.36 MB (48944.37 MB after compression)
1127139 655456      -90.7754    40      -51.0000     -363.8939 73547001   613.52%
1130118 657939     -351.8666   276      -51.0000     -363.8281 73617943   613.39%
1132460 659122     -340.0214   322      -51.0000     -363.8281 73638023   613.39%
1135268 661999     -350.3458   253      -51.0000     -363.8281 73703788   613.39%
1138155 663270     -349.7733   221      -51.0000     -363.7914 73727031   613.32%
1141315 666997     -109.6681    61      -51.0000     -363.7801 73803719   613.29%
1143035 667300     -319.7683   197      -51.0000     -363.7685 73809554   613.27%
1144567 670776     -253.0387   158      -51.0000     -363.7537 73913216   613.24%
1146521 670545     -259.3532   152      -51.0000     -363.7537 73901076   613.24%
1149449 672203     -348.4441   219      -51.0000     -363.7500 73968135   613.24%
Elapsed time = 2242.11 sec. (1391262.97 ticks, tree = 60633.18 MB, solutions = 37)
Nodefile size = 58549.92 MB (51084.18 MB after compression)
1152049 673941     -272.6028   196      -51.0000     -363.7500 74029925   613.24%
```

```
1154335 675960     -232.3749   144      -51.0000     -363.7346 74096293  613.21%
1156256 677959     -342.2852   228      -51.0000     -363.7346 74162994  613.21%
1158262 679301     -283.8515   185      -51.0000     -363.7346 74213670  613.21%
1160659 681152     -329.8099   233      -51.0000     -363.7346 74291318  613.21%
1163080 682052     -356.6172   229      -51.0000     -363.7346 74302383  613.21%
1164962 684898     -239.2677   149      -51.0000     -363.7346 74363108  613.21%
1166859 686253     -215.5065   147      -51.0000     -363.7035 74429048  613.14%
1169268 687434     -137.5978    79      -51.0000     -363.7026 74462687  613.14%
1171545 689622     -209.2428   119      -51.0000     -363.7026 74521715  613.14%
Elapsed time = 2302.32 sec. (1429431.71 ticks, tree = 61810.58 MB, solutions = 37)
Nodefile size = 59703.04 MB (52075.58 MB after compression)
1173411 692218     -356.7395   294      -51.0000     -363.7002 74586749  613.14%
1175378 692552     -168.7210    87      -51.0000     -363.6861 74594723  613.11%
1177260 694405     -353.1794   310      -51.0000     -363.6861 74666144  613.11%
1178498 695421     -323.5001   196      -51.0000     -363.6825 74706969  613.10%
1180148 696748     -157.0337    90      -51.0000     -363.6825 74757697  613.10%
1181894 698492     -174.7770   102      -51.0000     -363.6749 74851125  613.09%
1183386 700062      -74.6611    40      -51.0000     -363.6749 74931587  613.09%
1185302 699922      -80.6800    35      -51.0000     -363.6678 74926413  613.07%
1186617 701400     -271.7142   167      -51.0000     -363.6671 74988295  613.07%
1189228 702436     -317.6486   188      -51.0000     -363.6556 75016408  613.05%
Elapsed time = 2360.98 sec. (1467594.59 ticks, tree = 62502.87 MB, solutions = 37)
Nodefile size = 60366.86 MB (52639.96 MB after compression)
1191792 705430     -255.5873   151      -51.0000     -363.6524 75108073  613.04%
1194437 706237     -124.2892    69      -51.0000     -363.6470 75131286  613.03%
1197089 707759     -307.1593   218      -51.0000     -363.6470 75162684  613.03%
1199984 710769     -130.2921    67      -51.0000     -363.6466 75226744  613.03%
1202782 713542    infeasible            -51.0000     -363.6466 75289008  613.03%
1205543 714868     -250.1788   148      -51.0000     -363.6466 75306792  613.03%
1207640 716798     -324.8750   197      -51.0000     -363.6272 75347915  612.99%
1209905 717923     -274.8872   173      -51.0000     -363.6272 75381128  612.99%
1211507 720196     -128.8731    68      -51.0000     -363.6147 75451092  612.97%
1212988 721254     -185.9255   105      -51.0000     -363.6147 75476208  612.97%
Elapsed time = 2430.66 sec. (1505753.18 ticks, tree = 65025.03 MB, solutions = 37)
Nodefile size = 62942.95 MB (54909.80 MB after compression)
1214464 721679     -114.8208    59      -51.0000     -363.6147 75481562  612.97%
1216487 723625     -345.3600   243      -51.0000     -363.6147 75547226  612.97%
1218075 723995     -323.9574   195      -51.0000     -363.6134 75552962  612.97%
1219748 725238     -302.7574   216      -51.0000     -363.6134 75612915  612.97%
```

```
1221521 726612     -361.9645   476      -51.0000     -363.5945 75637366  612.93%
1222967 728865     -342.9362   292      -51.0000     -363.5945 75726583  612.93%
1224384 730826     -247.8571   152      -51.0000     -363.5945 75797131  612.93%
1225757 731044     -330.0338   261      -51.0000     -363.5945 75791560  612.93%
1226952 732586     -258.1447   163      -51.0000     -363.5845 75882721  612.91%
1228618 732872     -321.9352   194      -51.0000     -363.5839 75927746  612.91%
Elapsed time = 2489.07 sec. (1543964.51 ticks, tree = 66176.85 MB, solutions = 37)
Nodefile size = 64093.97 MB (55912.45 MB after compression)
1230703 733149     -351.7396   436      -51.0000     -363.5839 75968280  612.91%
1233278 735609     -131.9364    71      -51.0000     -363.5839 76043170  612.91%
1234652 737416     -235.5213   139      -51.0000     -363.5839 76127813  612.91%
1236454 738419     -181.1871   107      -51.0000     -363.5549 76156762  612.85%
1237699 740772     -129.0000    66      -51.0000     -363.5549 76254593  612.85%
1239535 740626     -147.0000    76      -51.0000     -363.5501 76250246  612.84%
1241284 742271     -246.1793   138      -51.0000     -363.5421 76335355  612.83%
1243215 744506     -336.5570   217      -51.0000     -363.5421 76435943  612.83%
1245194 745177     -297.8112   177      -51.0000     -363.5421 76453687  612.83%
1247711 747555     -348.0724   218      -51.0000     -363.5421 76533897  612.83%
Elapsed time = 2544.68 sec. (1582125.76 ticks, tree = 66528.97 MB, solutions = 37)
Nodefile size = 64413.10 MB (56160.38 MB after compression)
1250771 749319     -339.8761   240      -51.0000     -363.5421 76568677  612.83%
1253428 749875     -124.3338    66      -51.0000     -363.5421 76582998  612.83%
1255484 752046     -313.9867   199      -51.0000     -363.5421 76616090  612.83%
1257505 755090     -350.9171   242      -51.0000     -363.5421 76681612  612.83%
1260061 756810     -221.2307   125      -51.0000     -363.5421 76709254  612.83%
1262802 758964     -239.4641   151      -51.0000     -363.5421 76823900  612.83%
1266020 760556      -67.0000    27      -51.0000     -363.5421 76853753  612.83%
1268615 762001     -360.4381   313      -51.0000     -363.5421 76882255  612.83%
1270717 764173     -272.7824   204      -51.0000     -363.5421 76921149  612.83%
1273013 764966     -349.1395   221      -51.0000     -363.5421 76934663  612.83%
Elapsed time = 2612.51 sec. (1620287.49 ticks, tree = 68888.14 MB, solutions = 37)
Nodefile size = 66752.03 MB (58218.78 MB after compression)
1274910 766152     -207.9977   119      -51.0000     -363.5421 76966938  612.83%
1276895 767806     -303.6618   187      -51.0000     -363.5421 77002202  612.83%
1279341 770025      -65.0000    32      -51.0000     -363.5421 77074936  612.83%
1281908 771422     -347.6908   259      -51.0000     -363.5421 77108674  612.83%
1284101 773070     -177.3216    96      -51.0000     -363.5421 77190936  612.83%
1286070 776897     -256.3404   143      -51.0000     -363.5421 77312454  612.83%
1287980 777168     -310.7619   207      -51.0000     -363.5421 77318855  612.83%
```

```
1290484 778922     -188.5016   112      -51.0000     -363.5421 77387526  612.83%
1293069 781489     -349.1820   220      -51.0000     -363.5421 77460748  612.83%
1296398 783285      -98.9651    55      -51.0000     -363.4446 77499923  612.64%
Elapsed time = 2669.17 sec. (1658442.71 ticks, tree = 70071.06 MB, solutions = 37)
Nodefile size = 67958.53 MB (59253.49 MB after compression)
1299543 786097     -336.3001   223      -51.0000     -363.4300 77552721  612.61%
1303025 787564     -273.5397   156      -51.0000     -363.4226 77573312  612.59%
1306367 789080     -165.2899    99      -51.0000     -363.4165 77602295  612.58%
1309683 790823     -118.8209    58      -51.0000     -363.4165 77631755  612.58%
1312927 792605     -219.8976   134      -51.0000     -363.4015 77657849  612.55%
1315995 795803     -116.3636    55      -51.0000     -363.3930 77719274  612.54%
1318964 798022     -189.8624   104      -51.0000     -363.3865 77756398  612.52%
1322287 801721     -105.9631    46      -51.0000     -363.3788 77824176  612.51%
1325904 803857     -200.5226   112      -51.0000     -363.3710 77862574  612.49%
1328164 806865     -213.8837   137      -51.0000     -363.3676 77911316  612.49%
Elapsed time = 2740.62 sec. (1696601.21 ticks, tree = 73281.65 MB, solutions = 37)
Nodefile size = 71175.40 MB (62084.28 MB after compression)
1330725 808432     -253.4076   158      -51.0000     -363.3637 77946512  612.48%
1333424 811368      -83.0000    38      -51.0000     -363.3566 77996494  612.46%
1335998 812588     -207.2111   132      -51.0000     -363.3501 78032150  612.45%
1338136 815838     -262.3210   156      -51.0000     -363.3501 78120654  612.45%
1340355 816178      -79.0000    32      -51.0000     -363.3501 78126079  612.45%
1342750 818717     -179.9456   121      -51.0000     -363.3501 78197929  612.45%
1344977 819655      -64.0000    23      -51.0000     -363.3495 78246621  612.45%
1347424 820968     -220.0034   147      -51.0000     -363.3341 78263692  612.42%
1350340 824500     -337.0347   270      -51.0000     -363.3323 78361658  612.42%
1353068 826086     -218.3378   126      -51.0000     -363.3240 78392139  612.40%
Elapsed time = 2808.76 sec. (1734769.59 ticks, tree = 75570.94 MB, solutions = 37)
Nodefile size = 73464.03 MB (64075.14 MB after compression)
1354929 828737     -249.5033   167      -51.0000     -363.3240 78453276  612.40%
1357188 828878      -58.0000    31      -51.0000     -363.3240 78474265  612.40%
1360989 829429     -120.5256    54      -51.0000     -363.3071 78489831  612.37%
1363767 832535     -233.8816   139      -51.0000     -363.3009 78554923  612.35%
1366058 836220     -353.4513   283      -51.0000     -363.3009 78615429  612.35%
1368168 836811     -168.0117    96      -51.0000     -363.2916 78636188  612.34%
1370621 838448     -150.5858    71      -51.0000     -363.2852 78668575  612.32%
1373310 840832     -192.6639   118      -51.0000     -363.2852 78723896  612.32%
1376021 842744     -116.0000    61      -51.0000     -363.2846 78755757  612.32%
1378544 843891     -303.4139   177      -51.0000     -363.2846 78798222  612.32%
```

```
Elapsed time = 2876.38 sec. (1772947.12 ticks, tree = 78009.93 MB, solutions = 37)
Nodefile size = 75864.31 MB (66187.42 MB after compression)
1380852 844714     -104.8889    54      -51.0000     -363.2846 78805091  612.32%
1382951 849567     -266.2673   184      -51.0000     -363.2846 78916286  612.32%
1385337 849918     -354.9558   288      -51.0000     -363.2591 78921259  612.27%
1387121 850980     -220.9833   127      -51.0000     -363.2554 78943781  612.27%
1388896 853784     -311.5685   191      -51.0000     -363.2506 79021815  612.26%
1390673 854058     -319.6543   213      -51.0000     -363.2506 79027093  612.26%
1392561 856415     -215.9617   135      -51.0000     -363.2506 79109073  612.26%
1394362 856773     -336.7539   231      -51.0000     -363.2487 79114447  612.25%
1396269 858330     -314.7448   196      -51.0000     -363.2487 79170234  612.25%
1398329 859496     -278.4522   165      -51.0000     -363.2457 79188574  612.25%
Elapsed time = 2939.17 sec. (1811109.90 ticks, tree = 80161.14 MB, solutions = 37)
Nodefile size = 77996.90 MB (68060.51 MB after compression)
1400362 861629      -94.8928    60      -51.0000     -363.2457 79278236  612.25%
1402182 863414     -210.8249   123      -51.0000     -363.2457 79322997  612.25%
1403647 864988     -356.3679   277      -51.0000     -363.2134 79365317  612.18%
1405435 865338     -146.7865    78      -51.0000     -363.2088 79370410  612.17%
1406589 867010     -359.7785   358      -51.0000     -363.2088 79449597  612.17%
1407357 867801     -175.8509   103      -51.0000     -363.2088 79473735  612.17%
1408480 869141     -357.7632   286      -51.0000     -363.2060 79559155  612.17%
1409072 869005     -292.4575   185      -51.0000     -363.2030 79576725  612.16%
1409931 870613     -317.9388   207      -51.0000     -363.2030 79678668  612.16%
1410846 871221     -300.5855   191      -51.0000     -363.2030 79725732  612.16%
Elapsed time = 3001.29 sec. (1849268.80 ticks, tree = 81426.69 MB, solutions = 37)
Nodefile size = 79340.13 MB (69235.09 MB after compression)
1412565 871839     -198.5468   146      -51.0000     -363.1993 79794879  612.16%
1414222 872610     -355.1605   245      -51.0000     -363.1976 79824561  612.15%
1416451 873746     -136.8493    75      -51.0000     -363.1940 79887929  612.15%
1418802 875876     -262.7594   150      -51.0000     -363.1940 79985747  612.15%
1420667 877986     -120.8353    67      -51.0000     -363.1940 80044684  612.15%
1422897 879153      -68.0000    29      -51.0000     -363.1912 80105755  612.14%
1424675 880527     -102.5792    49      -51.0000     -363.1912 80124655  612.14%
1426442 881127     -214.1609   129      -51.0000     -363.1912 80157146  612.14%
1428467 883401     -182.3962   109      -51.0000     -363.1707 80225126  612.10%
1430584 885240     -157.4481    95      -51.0000     -363.1701 80286129  612.10%
Elapsed time = 3060.58 sec. (1887439.56 ticks, tree = 82485.78 MB, solutions = 37)
Nodefile size = 80396.88 MB (70146.52 MB after compression)
1431870 886774     -284.1700   176      -51.0000     -363.1701 80338190  612.10%
```

```
1433655 887329     -192.0080   106      -51.0000     -363.1701 80363893  612.10%
1435683 887996     -221.9601   130      -51.0000     -363.1701 80378007  612.10%
1437806 890614     -173.4306    90      -51.0000     -363.1701 80521614  612.10%
1439772 890705     -346.6358   222      -51.0000     -363.1634 80541956  612.09%
1441413 894088     -326.9882   225      -51.0000     -363.1634 80639579  612.09%
1443300 893400      -70.0000    28      -51.0000     -363.1542 80610357  612.07%
1445035 896243     -208.7591   119      -51.0000     -363.1453 80712144  612.05%
1446281 897127     -197.6167   112      -51.0000     -363.1419 80754887  612.04%
1447762 898657      -91.8217    40      -51.0000     -363.1419 80807489  612.04%
Elapsed time = 3123.21 sec. (1925598.32 ticks, tree = 83544.11 MB, solutions = 37)
Nodefile size = 81452.99 MB (71050.24 MB after compression)
1449076 899736     -322.1691   203      -51.0000     -363.1419 80869707  612.04%
1450689 899823     -232.5075   136      -51.0000     -363.1318 80862276  612.02%
1452809 901413     -225.7858   139      -51.0000     -363.1314 80941867  612.02%
1454893 903274     -358.8973   388      -51.0000     -363.1282 81042552  612.02%
1457193 905392     -173.3702    95      -51.0000     -363.1282 81100657  612.02%
1459630 905749     -248.7621   160      -51.0000     -363.1229 81106133  612.01%
1462412 908405     -327.4000   317      -51.0000     -363.1193 81191230  612.00%
1465284 910018     -269.0734   163      -51.0000     -363.1193 81234773  612.00%
1467995 911192     -127.3125    68      -51.0000     -363.1193 81272725  612.00%
1470171 915051     -214.2308   131      -51.0000     -363.1193 81338792  612.00%
Elapsed time = 3185.87 sec. (1963768.00 ticks, tree = 85097.25 MB, solutions = 37)
Nodefile size = 82996.73 MB (72399.07 MB after compression)
1472123 915840      -61.2873    25      -51.0000     -363.0963 81359705  611.95%
1474944 917352     -150.6935   103      -51.0000     -363.0963 81406102  611.95%
1477413 918699     -206.5598   113      -51.0000     -363.0963 81437361  611.95%
1480258 921424     -164.2992   111      -51.0000     -363.0819 81482776  611.93%
1482580 921768     -268.5418   165      -51.0000     -363.0819 81488923  611.93%
1485060 924969     -143.3574    86      -51.0000     -363.0736 81569087  611.91%
1487196 925334     -228.5638   136      -51.0000     -363.0736 81574482  611.91%
1488705 927554     -163.6258   104      -51.0000     -363.0736 81634624  611.91%
1490312 928638     -309.5214   190      -51.0000     -363.0642 81673852  611.89%
1491785 929380     -358.3981   270      -51.0000     -363.0642 81684293  611.89%
Elapsed time = 3251.39 sec. (2001939.32 ticks, tree = 87079.65 MB, solutions = 37)
Nodefile size = 84914.94 MB (74090.46 MB after compression)
1493123 932100     -361.1607   431      -51.0000     -363.0642 81782395  611.89%
1494409 933384     -226.9344   133      -51.0000     -363.0459 81815947  611.85%
1495695 934332     -340.4590   462      -51.0000     -363.0412 81876672  611.85%
1496875 935790      -83.4127    43      -51.0000     -363.0360 81930955  611.84%
```

```
1498611 936080     -340.2493   219      -51.0000     -363.0359 81938184  611.84%
1500352 938166     -344.8650   243      -51.0000     -363.0359 82058846  611.84%
1501886 939423     -214.2697   147      -51.0000     -363.0359 82133186  611.84%
1504021 940301     -358.9608   298      -51.0000     -363.0299 82162519  611.82%
1505915 940547     -111.5071    60      -51.0000     -363.0219 82169070  611.81%
1508308 942596     -290.0645   164      -51.0000     -363.0181 82259386  611.80%
Elapsed time = 3310.11 sec. (2040140.88 ticks, tree = 87780.04 MB, solutions = 37)
Nodefile size = 85628.88 MB (74705.56 MB after compression)
1509877 943462     -362.1250   345      -51.0000     -363.0181 82279281  611.80%
1511487 944392     -250.2819   153      -51.0000     -363.0181 82311234  611.80%
1513253 946218     -108.1399    52      -51.0000     -363.0181 82347204  611.80%
1515387 948834     -189.7285   105      -51.0000     -363.0181 82452582  611.80%
1517182 949556      -75.4540    32      -51.0000     -363.0181 82477198  611.80%
1519399 949444    infeasible            -51.0000     -363.0181 82514269  611.80%
1521136 952636     -323.2530   196      -51.0000     -363.0181 82576083  611.80%
1522540 953923     -233.5832   139      -51.0000     -363.0181 82642685  611.80%
1524673 955141     -324.2844   195      -51.0000     -363.0181 82669446  611.80%
1527134 957400     -270.0783   153      -51.0000     -363.0181 82761101  611.80%
Elapsed time = 3375.30 sec. (2078300.10 ticks, tree = 89832.75 MB, solutions = 37)
Nodefile size = 87735.09 MB (76556.10 MB after compression)
1529246 958614     -201.0558   130      -51.0000     -362.9817 82793638  611.73%
1531688 958996     -161.7118    88      -51.0000     -362.9817 82798680  611.73%
1533866 961145     -311.7875   206      -51.0000     -362.9680 82872188  611.70%
1536179 963907     -186.8495   106      -51.0000     -362.9665 82919347  611.70%
1538696 963676     -352.0906   262      -51.0000     -362.9639 82919358  611.69%
1541291 967962     -352.4511   278      -51.0000     -362.9596 83060386  611.69%
1543733 968242     -357.3868   235      -51.0000     -362.9596 83066483  611.69%
1546056 969753     -131.0000    70      -51.0000     -362.9596 83094379  611.69%
1548313 973663     -358.5955   292      -51.0000     -362.9596 83188282  611.69%
1550146 974076     -337.6329   235      -51.0000     -362.9596 83193612  611.69%
Elapsed time = 3438.78 sec. (2116458.32 ticks, tree = 91621.92 MB, solutions = 37)
Nodefile size = 89472.03 MB (78071.33 MB after compression)
1552066 975198     -257.4841   153      -51.0000     -362.9596 83217109  611.69%
1554054 978192     -362.7689   413      -51.0000     -362.9596 83329259  611.69%
1555755 978851     -143.0000    75      -51.0000     -362.9596 83355737  611.69%
1557601 980081     -111.0000    62      -51.0000     -362.9596 83402580  611.69%
1559461 980883      -65.5000    31      -51.0000     -362.9596 83416493  611.69%
1561060 981959      -95.2712    54      -51.0000     -362.9596 83457941  611.69%
1563252 984242     -362.0169   413      -51.0000     -362.9596 83525920  611.69%
```

```
1565359 985051     -357.4587   294      -51.0000     -362.9233 83550747  611.61%
1567576 986032     -149.0000    85      -51.0000     -362.9233 83574660  611.61%
1569513 987717     -279.5274   163      -51.0000     -362.9233 83634697  611.61%
Elapsed time = 3504.02 sec. (2154615.60 ticks, tree = 93479.99 MB, solutions = 37)
Nodefile size = 91371.26 MB (79754.57 MB after compression)
1571974 990722     -362.4365   380      -51.0000     -362.9233 83694670  611.61%
1573897 992646      -68.4032    28      -51.0000     -362.9114 83746398  611.59%
1575392 992729     -330.2044   206      -51.0000     -362.9114 83779146  611.59%
1577047 993978     -358.7650   359      -51.0000     -362.9057 83809952  611.58%
1578890 995730     -127.0000    61      -51.0000     -362.8989 83877449  611.57%
1580686 998467     -287.4760   169      -51.0000     -362.8989 83985755  611.57%
1582486 998774     -184.8990    96      -51.0000     -362.8989 83990762  611.57%
1584991 998842     -356.8110   390      -51.0000     -362.8859 84005528  611.54%
1587493 999579      -77.0000    35      -51.0000     -362.8859 84044828  611.54%
1589567 1002790     -131.3414    85      -51.0000     -362.8732 84134590  611.52%
Elapsed time = 3565.26 sec. (2192780.39 ticks, tree = 94791.64 MB, solutions = 37)
Nodefile size = 92672.34 MB (80888.26 MB after compression)
1592670 1004787     -297.9113   190      -51.0000     -362.8725 84180248  611.51%
1595731 1005466      -95.7042    50      -51.0000     -362.8672 84210720  611.50%
1599386 1006137     -255.3546   166      -51.0000     -362.8664 84220217  611.50%
1602374 1011809     -258.4069   167      -51.0000     -362.8652 84331862  611.50%
1604997 1010524     -360.4317   388      -51.0000     -362.8581 84307783  611.49%
1607859 1015041     -290.6650   167      -51.0000     -362.8530 84391761  611.48%
1610787 1017262     -348.8495   243      -51.0000     -362.8508 84436563  611.47%
1613632 1021191     -135.1203    72      -51.0000     -362.8508 84518537  611.47%
1615516 1020433     -216.2144   140      -51.0000     -362.8410 84504224  611.45%
1617251 1022386     -270.4581   162      -51.0000     -362.8333 84547261  611.44%
Elapsed time = 3635.70 sec. (2230941.04 ticks, tree = 97508.37 MB, solutions = 37)
Nodefile size = 95355.95 MB (83241.89 MB after compression)
1619480 1026326     -106.0000    53      -51.0000     -362.8282 84646400  611.43%
1621653 1026348     -355.3272   241      -51.0000     -362.8246 84638448  611.42%
1624106 1028420     -165.5907   118      -51.0000     -362.8246 84737509  611.42%
1626046 1031119     -197.2253   111      -51.0000     -362.8246 84803674  611.42%
1628354 1031483     -272.8441   187      -51.0000     -362.8182 84808486  611.41%
1630900 1033785     -136.0000    74      -51.0000     -362.8149 84879529  611.40%
1633280 1035225     -178.0256   106      -51.0000     -362.8095 84897759  611.39%
1635519 1036730     -352.3538   246      -51.0000     -362.8073 84951001  611.39%
1637650 1037407     -127.6583    75      -51.0000     -362.8062 84968280  611.38%
1640581 1037971     -353.0674   237      -51.0000     -362.8062 84995175  611.38%
```

```
Elapsed time = 3699.91 sec. (2269105.18 ticks, tree = 99299.35 MB, solutions = 37)
Nodefile size = 97165.67 MB (84826.35 MB after compression)
1643113 1042917     -123.0000    65       -51.0000     -362.7964 85104583   611.37%
1645682 1045072      -98.0000    43       -51.0000     -362.7915 85155504   611.36%
1647968 1044321     -247.7274   144       -51.0000     -362.7915 85146785   611.36%
1649894 1048126     -262.8989   152       -51.0000     -362.7845 85227817   611.34%
1651814 1049151     -186.8173   101       -51.0000     -362.7845 85253195   611.34%
1653327 1049473     -356.1169   318       -51.0000     -362.7795 85258164   611.33%
1655002 1053056     -355.6073   278       -51.0000     -362.7795 85359222   611.33%
1656520 1053373     -135.0000    67       -51.0000     -362.7795 85407938   611.33%
1658361 1054656     -101.0000    57       -51.0000     -362.7795 85449771   611.33%
1659888 1055695     -256.1699   146       -51.0000     -362.7795 85516761   611.33%
Elapsed time = 3765.79 sec. (2307266.26 ticks, tree = 101441.55 MB, solutions = 37)
Nodefile size = 99318.60 MB (86720.36 MB after compression)
1661149 1056024     -127.0000    72       -51.0000     -362.7795 85521668   611.33%
1662587 1057258     -353.0349   265       -51.0000     -362.7795 85568921   611.33%
1663677 1059201     -312.0521   192       -51.0000     -362.7795 85649252   611.33%
1665018 1060718     -346.8945   253       -51.0000     -362.7795 85699888   611.33%
1667093 1061145     -233.1731   124       -51.0000     -362.7795 85762078   611.33%
1668662 1063518     -185.8541    99       -51.0000     -362.7540 85814491   611.28%
1670566 1063921     -292.5807   179       -51.0000     -362.7471 85869834   611.27%
1673003 1064269      -93.0000    51       -51.0000     -362.7471 85876458   611.27%
1674618 1066561     -318.0390   230       -51.0000     -362.7460 85962658   611.27%
1676422 1066460     -355.5526   277       -51.0000     -362.7419 85956170   611.26%
Elapsed time = 3822.33 sec. (2345444.75 ticks, tree = 102413.17 MB, solutions = 37)
Nodefile size = 100313.89 MB (87590.71 MB after compression)
1678428 1069357     -120.0000    61       -51.0000     -362.7356 86082885   611.25%
1680900 1070444     -127.0000    79       -51.0000     -362.7356 86127269   611.25%
1684018 1072004     -195.2310   115       -51.0000     -362.7356 86162816   611.25%
1686950 1074672     -198.9341   121       -51.0000     -362.7213 86217540   611.22%
1688817 1075569     -344.0144   261       -51.0000     -362.7205 86234976   611.22%
1690232 1077618     -349.8671   358       -51.0000     -362.7205 86267376   611.22%
1692562 1078890     -230.6096   136       -51.0000     -362.7201 86305304   611.22%
1694242 1081904      -93.0000    43       -51.0000     -362.7066 86455402   611.19%
1695461 1080671     -211.5977   136       -51.0000     -362.7044 86405574   611.19%
1697499 1082638     -347.2280   227       -51.0000     -362.7018 86477065   611.18%
Elapsed time = 3887.72 sec. (2383611.26 ticks, tree = 103831.56 MB, solutions = 37)
Nodefile size = 101675.30 MB (88760.66 MB after compression)
1699409 1083919     -347.0445   252       -51.0000     -362.7018 86523820   611.18%
```

```
1701903 1087178     -164.0000    86      -51.0000     -362.6903 86637076  611.16%
1705244 1087473     -111.0000    54      -51.0000     -362.6903 86641463  611.16%
1708528 1091154     -351.8627   327      -51.0000     -362.6816 86710675  611.14%
1711345 1091455     -305.5254   226      -51.0000     -362.6810 86716115  611.14%
1714058 1093531     -125.0000    68      -51.0000     -362.6810 86742733  611.14%
1716044 1093882     -270.4370   177      -51.0000     -362.6810 86747997  611.14%
1717546 1096977     -165.0000    85      -51.0000     -362.6732 86820470  611.12%
1718830 1098665     -355.7772   430      -51.0000     -362.6672 86862102  611.11%
1720069 1100901     -135.0000    80      -51.0000     -362.6656 86925829  611.11%
Elapsed time = 3953.78 sec. (2421784.63 ticks, tree = 106417.14 MB, solutions = 37)
Nodefile size = 104319.82 MB (91096.33 MB after compression)
1721339 1101680     -117.0000    56      -51.0000     -362.6656 86974958  611.11%
1722319 1102272     -218.3016   136      -51.0000     -362.6596 87030638  611.10%
1723245 1103269     -275.9999   162      -51.0000     -362.6596 87056591  611.10%
1724223 1103312      -96.0000    46      -51.0000     -362.6596 87073826  611.10%
1725584 1104731     -177.3169   117      -51.0000     -362.6596 87136461  611.10%
1726911 1106217     -188.3971   143      -51.0000     -362.6574 87241554  611.09%
1728561 1106444     -176.0748    89      -51.0000     -362.6574 87287791  611.09%
1730521 1108181     -327.5582   201      -51.0000     -362.6574 87316342  611.09%
1732599 1108551      -74.0000    35      -51.0000     -362.6574 87322004  611.09%
1734632 1110364     -337.1043   250      -51.0000     -362.6574 87399542  611.09%
Elapsed time = 4014.37 sec. (2459957.65 ticks, tree = 107224.35 MB, solutions = 37)
Nodefile size = 105067.96 MB (91749.43 MB after compression)
1737166 1112205     -193.2310   114      -51.0000     -362.6459 87446556  611.07%
1739419 1112996     -173.7686    92      -51.0000     -362.6459 87486378  611.07%
1741249 1114769     -347.1913   214      -51.0000     -362.6401 87522106  611.06%
1743358 1115064     -192.2962   107      -51.0000     -362.6384 87515063  611.06%
1744968 1118074     -328.4236   210      -51.0000     -362.6359 87592968  611.05%
1746865 1119076     -191.1902   112      -51.0000     -362.6287 87643898  611.04%
1748365 1121241      -81.0000    37      -51.0000     -362.6225 87699408  611.02%
1750085 1121481     -324.0813   201      -51.0000     -362.6225 87705667  611.02%
1752508 1124145      -60.0000    19      -51.0000     -362.6205 87805130  611.02%
1755390 1123880    infeasible            -51.0000     -362.6205 87785448  611.02%
Elapsed time = 4081.48 sec. (2498117.32 ticks, tree = 109186.03 MB, solutions = 37)
Nodefile size = 107010.45 MB (93469.83 MB after compression)
1757833 1127056     -215.2144   120      -51.0000     -362.6205 87862964  611.02%
1759906 1130330     -126.6583    64      -51.0000     -362.6205 87942162  611.02%
1761605 1131195     -158.9016    98      -51.0000     -362.6205 87952404  611.02%
1763935 1132655     -353.8302   251      -51.0000     -362.6059 88000738  610.99%
```

```
1766383 1135120     -358.4267   298      -51.0000     -362.5995 88069117  610.98%
1769340 1134674     -351.0958   290      -51.0000     -362.5959 88065237  610.97%
1770949 1137435     -354.5922   298      -51.0000     -362.5959 88133999  610.97%
1772901 1138195     -317.6154   230      -51.0000     -362.5891 88152987  610.96%
1774852 1138989     -319.6824   186      -51.0000     -362.5858 88197180  610.95%
1777181 1141667     -228.0794   142      -51.0000     -362.5778 88238065  610.94%
Elapsed time = 4149.17 sec. (2536284.58 ticks, tree = 111606.07 MB, solutions = 37)
Nodefile size = 109464.13 MB (95628.95 MB after compression)
1779471 1142822     -356.9082   300      -51.0000     -362.5778 88301076  610.94%
1781560 1145486     -345.4786   300      -51.0000     -362.5709 88354961  610.92%
1783964 1146383     -142.0000    75      -51.0000     -362.5683 88384760  610.92%
1786599 1149409     -156.9016    93      -51.0000     -362.5632 88449409  610.91%
1788528 1150674     -286.3848   175      -51.0000     -362.5575 88476984  610.90%
1790262 1152003     -152.8889    82      -51.0000     -362.5554 88530369  610.89%
1792157 1154316     -312.5151   205      -51.0000     -362.5519 88608998  610.89%
1794239 1155329      -81.4111    38      -51.0000     -362.5519 88632851  610.89%
1796795 1155687     -226.8191   121      -51.0000     -362.5490 88638195  610.88%
1798889 1157971     -242.5105   141      -51.0000     -362.5490 88695455  610.88%
Elapsed time = 4216.83 sec. (2574439.80 ticks, tree = 113971.04 MB, solutions = 37)
Nodefile size = 111820.30 MB (97713.78 MB after compression)
1801257 1160786     -326.2609   217      -51.0000     -362.5476 88785387  610.88%
1803904 1160584     -197.5598   116      -51.0000     -362.5476 88778037  610.88%
1806916 1163684     -112.0000    59      -51.0000     -362.5476 88855097  610.88%
1809860 1164061     -164.0000    89      -51.0000     -362.5359 88860117  610.85%
1812427 1167790     -353.8110   266      -51.0000     -362.5338 88946081  610.85%
1813938 1169137     -355.4961   313      -51.0000     -362.5313 88984565  610.85%
1815156 1169515      -95.0000    50      -51.0000     -362.5280 88989276  610.84%
1816884 1172293     -109.0000    56      -51.0000     -362.5280 89054712  610.84%
1819029 1172222     -359.4854   274      -51.0000     -362.5165 89088292  610.82%
1820702 1175341     -101.0000    59      -51.0000     -362.5139 89172352  610.81%
Elapsed time = 4283.62 sec. (2612607.16 ticks, tree = 116452.58 MB, solutions = 37)
Nodefile size = 114352.58 MB (99959.10 MB after compression)
1821717 1175520     -316.6016   211      -51.0000     -362.5105 89178976  610.80%
1822802 1175743     -356.9446   302      -51.0000     -362.5105 89208707  610.80%
1825186 1177728     -359.8573   307      -51.0000     -362.5019 89292196  610.79%
1828466 1178524     -311.3564   177      -51.0000     -362.4955 89352642  610.78%
1831697 1179704     -254.7012   147      -51.0000     -362.4947 89383091  610.77%
1833684 1185363     -346.5593   242      -51.0000     -362.4913 89494458  610.77%
1835958 1185747      -65.0000    35      -51.0000     -362.4905 89499237  610.77%
```

```
1838222 1187800     -349.6080   333      -51.0000     -362.4905 89556219  610.77%
1840349 1189274     -190.9810   106      -51.0000     -362.4891 89593726  610.76%
1842574 1190077     -131.0000    66      -51.0000     -362.4891 89607149  610.76%
Elapsed time = 4348.73 sec. (2650771.96 ticks, tree = 118254.77 MB, solutions = 37)
Nodefile size = 116123.16 MB (101513.80 MB after compression)
1844137 1190950     -337.9764   239      -51.0000     -362.4773 89621043  610.74%
1845868 1194067     -163.0000    91      -51.0000     -362.4773 89702644  610.74%
1847428 1194442    infeasible            -51.0000     -362.4773 89707519  610.74%
1848545 1195399     -338.9939   269      -51.0000     -362.4715 89749797  610.73%
1849976 1197189     -312.5297   186      -51.0000     -362.4715 89842164  610.73%
1852539 1197765     -172.7495   102      -51.0000     -362.4715 89864964  610.73%
1855071 1199117     -174.5109    95      -51.0000     -362.4673 89907349  610.72%
1857581 1199427      -79.0000    33      -51.0000     -362.4673 89912585  610.72%
1860128 1204628     -139.0000    78      -51.0000     -362.4673 90040175  610.72%
1862424 1204806      -92.0000    38      -51.0000     -362.4673 90046923  610.72%
Elapsed time = 4412.31 sec. (2688942.58 ticks, tree = 119835.92 MB, solutions = 37)
Nodefile size = 117703.76 MB (102891.72 MB after compression)
1864012 1205110     -334.7566   231      -51.0000     -362.4673 90052032  610.72%
1865715 1206430     -248.0777   143      -51.0000     -362.4673 90089209  610.72%
1867880 1208849     -360.7170   315      -51.0000     -362.4673 90124930  610.72%
1869710 1210002     -253.9861   148      -51.0000     -362.4461 90184073  610.68%
1871605 1212587     -271.6025   172      -51.0000     -362.4461 90320048  610.68%
1873471 1213584     -156.0000    98      -51.0000     -362.4461 90347220  610.68%
1875249 1215234     -346.3866   246      -51.0000     -362.4461 90387853  610.68%
1876789 1216880     -136.0000    70      -51.0000     -362.4317 90467261  610.65%
1878428 1216583     -360.9537   396      -51.0000     -362.4300 90462464  610.65%
1879496 1218118     -271.7228   172      -51.0000     -362.4300 90528095  610.65%
Elapsed time = 4475.52 sec. (2727125.87 ticks, tree = 121765.60 MB, solutions = 37)
Nodefile size = 119662.56 MB (104632.68 MB after compression)
1879927 1219133     -331.2837   228      -51.0000     -362.4208 90557727  610.63%
1881200 1219700     -354.6783   283      -51.0000     -362.4206 90586562  610.63%
1882723 1221442     -339.9416   253      -51.0000     -362.4201 90642101  610.63%
1883876 1222681     -353.1613   241      -51.0000     -362.4167 90733610  610.62%
1884976 1222419     -356.8062   237      -51.0000     -362.4167 90727814  610.62%
1885808 1224246     -174.6478    96      -51.0000     -362.4148 90820647  610.62%
1887127 1224675      -96.0000    47      -51.0000     -362.4143 90824870  610.62%
1888119 1226301     -354.7976   297      -51.0000     -362.4143 90942207  610.62%
1889542 1227449     -292.9870   200      -51.0000     -362.4143 90980258  610.62%
1891491 1227878     -201.0640   120      -51.0000     -362.4065 90984614  610.60%
```

```
Elapsed time = 4533.80 sec. (2765317.84 ticks, tree = 122538.28 MB, solutions = 37)
Nodefile size = 120337.04 MB (105215.91 MB after compression)
1893792 1227996     -162.0000     91       -51.0000     -362.4065 91035314  610.60%
1896328 1230354     -246.3380    142       -51.0000     -362.4053 91099099  610.60%
1898667 1232386     -348.0567    224       -51.0000     -362.4034 91151758  610.59%
1900424 1234216     -202.3876    116       -51.0000     -362.3982 91202203  610.58%
1902409 1235516     -146.0000     82       -51.0000     -362.3963 91228751  610.58%
1904297 1236559     -294.4467    221       -51.0000     -362.3939 91256879  610.58%
1905946 1237273     -169.0000     91       -51.0000     -362.3926 91297562  610.57%
1908247 1238212     -359.1546    327       -51.0000     -362.3923 91327857  610.57%
1910238 1241889      -93.0000     43       -51.0000     -362.3840 91454153  610.56%
1912123 1242108     -253.7352    161       -51.0000     -362.3840 91443338  610.56%
Elapsed time = 4597.07 sec. (2803482.88 ticks, tree = 124122.99 MB, solutions = 37)
Nodefile size = 121915.48 MB (106601.21 MB after compression)
1913823 1244810     -293.5904    165       -51.0000     -362.3840 91560056  610.56%
1915261 1242831     -348.9132    224       -51.0000     -362.3840 91487721  610.56%
1917087 1245691     -357.7825    398       -51.0000     -362.3736 91596278  610.54%
1919377 1247859     -350.8520    301       -51.0000     -362.3727 91640207  610.53%
1920957 1249365     -349.1644    264       -51.0000     -362.3727 91704716  610.53%
1922448 1251919     -241.0255    135       -51.0000     -362.3727 91787046  610.53%
1924299 1251385     -139.0000     89       -51.0000     -362.3727 91745691  610.53%
1925928 1254633     -335.5796    212       -51.0000     -362.3727 91864879  610.53%
1927733 1253942     -248.7582    148       -51.0000     -362.3727 91863422  610.53%
1929800 1254954     -161.5000     98       -51.0000     -362.3727 91914276  610.53%
Elapsed time = 4665.96 sec. (2841657.11 ticks, tree = 125876.31 MB, solutions = 37)
Nodefile size = 123736.62 MB (108198.02 MB after compression)
1932915 1257567     -356.6930    308       -51.0000     -362.3727 91971230  610.53%
1935557 1257895     -235.1592    138       -51.0000     -362.3485 91975728  610.49%
1937930 1259507     -133.0000     76       -51.0000     -362.3470 92043433  610.48%
1939112 1262952     -268.7837    146       -51.0000     -362.3423 92119640  610.48%
1941120 1263559     -336.0770    228       -51.0000     -362.3380 92141033  610.47%
1943317 1266134      -78.0000     38       -51.0000     -362.3380 92201328  610.47%
1945343 1266470      -81.0000     35       -51.0000     -362.3380 92230682  610.47%
1947101 1268368     -140.3414     74       -51.0000     -362.3309 92291980  610.45%
1948917 1269242     -223.0782    125       -51.0000     -362.3309 92327936  610.45%
1950788 1269706      -57.0000     25       -51.0000     -362.3309 92331814  610.45%
Elapsed time = 4731.66 sec. (2879825.80 ticks, tree = 127608.51 MB, solutions = 37)
Nodefile size = 125386.48 MB (109656.60 MB after compression)
1952593 1272828     -163.0000     86       -51.0000     -362.3309 92422770  610.45%
```

```
1955188 1273992     -348.8436   266       -51.0000     -362.3309 92476904  610.45%
1957494 1273935     -179.5526    97       -51.0000     -362.3309 92458164  610.45%
1958998 1275371     -357.5784   362       -51.0000     -362.3309 92499131  610.45%
1960528 1278994     -183.2555   100       -51.0000     -362.3309 92595513  610.45%
1962501 1279390     -143.0000    79       -51.0000     -362.3309 92614185  610.45%
1963753 1279515     -181.5109   103       -51.0000     -362.3309 92622257  610.45%
1965266 1282516     -101.0000    45       -51.0000     -362.3309 92718093  610.45%
1966607 1283982     -337.5188   281       -51.0000     -362.3309 92799904  610.45%
1968190 1282938     -315.7303   204       -51.0000     -362.3309 92761351  610.45%
Elapsed time = 4795.38 sec. (2917991.21 ticks, tree = 129154.59 MB, solutions = 37)
Nodefile size = 127050.39 MB (111116.43 MB after compression)
1970548 1286382     -334.5310   206       -51.0000     -362.3309 92905255  610.45%
1972793 1287538     -249.0323   140       -51.0000     -362.3309 92945474  610.45%
1974081 1286958     -223.8645   140       -51.0000     -362.3309 92914229  610.45%
1975090 1289465     -301.1046   172       -51.0000     -362.3309 93018059  610.45%
1976045 1288874     -355.0767   231       -51.0000     -362.3309 92974520  610.45%
1977011 1292121     -361.9902   290       -51.0000     -362.3309 93088426  610.45%
1978501 1293014     -358.8972   302       -51.0000     -362.3309 93119372  610.45%
1980427 1292664     -196.8761   136       -51.0000     -362.3074 93113119  610.41%
1981659 1294107      -96.5679    44       -51.0000     -362.3074 93290304  610.41%
1982761 1295504     -257.0260   157       -51.0000     -362.3074 93318116  610.41%
Elapsed time = 4857.33 sec. (2956165.23 ticks, tree = 130261.01 MB, solutions = 37)
Nodefile size = 128107.74 MB (112032.73 MB after compression)
1984197 1296305     -228.6609   123       -51.0000     -362.3074 93336345  610.41%
1985492 1296197     -177.2575   101       -51.0000     -362.3074 93393577  610.41%
1986946 1298745     -119.0000    59       -51.0000     -362.3074 93460887  610.41%
1988715 1298777     -360.0183   343       -51.0000     -362.3074 93496963  610.41%
1990344 1301907     -355.9441   253       -51.0000     -362.3074 93607408  610.41%
1992706 1302258     -120.0000    62       -51.0000     -362.2874 93612558  610.37%
1995018 1304182     -225.4859   128       -51.0000     -362.2874 93683921  610.37%
1997601 1303431     -155.8836    85       -51.0000     -362.2874 93659824  610.37%
1999960 1306782     -179.7059   100       -51.0000     -362.2874 93741768  610.37%
2001806 1307133     -277.2162   157       -51.0000     -362.2534 93746417  610.30%
Elapsed time = 4924.31 sec. (2994343.65 ticks, tree = 131623.21 MB, solutions = 37)
Nodefile size = 129402.80 MB (113165.07 MB after compression)
2003608 1310011        cutoff             -51.0000     -362.2505 93852745  610.30%
2005876 1311929     -360.7152   340       -51.0000     -362.2420 93872511  610.28%
2007520 1314349     -361.2690   324       -51.0000     -362.2401 93949400  610.27%
2010050 1315474     -358.1109   347       -51.0000     -362.2348 93980261  610.26%
```

```
2012141 1314837     -121.0000    78      -51.0000     -362.2319 93967126  610.26%
2014117 1316900     -210.4484   137      -51.0000     -362.2319 94047490  610.26%
2016539 1320203     -301.7363   185      -51.0000     -362.2225 94177706  610.24%
2018363 1319559      -90.0000    35      -51.0000     -362.2210 94148369  610.24%
2019749 1322440     -109.2500    66      -51.0000     -362.2210 94261607  610.24%
2021774 1322860     -353.5627   239      -51.0000     -362.2210 94250994  610.24%
Elapsed time = 4990.11 sec. (3032511.21 ticks, tree = 133163.44 MB, solutions = 37)
Nodefile size = 130977.97 MB (114541.34 MB after compression)
2023532 1324766     -201.9114   114      -51.0000     -362.2210 94318165  610.24%
2025242 1327799     -353.9849   299      -51.0000     -362.2100 94439879  610.22%
2026170 1326401     -158.0000    94      -51.0000     -362.2098 94361700  610.22%
2026901 1329537     -287.7297   180      -51.0000     -362.2078 94472233  610.21%
2028133 1330094      -58.4032    26      -51.0000     -362.2078 94513762  610.21%
2029923 1331143      -65.4032    29      -51.0000     -362.2065 94618610  610.21%
2031440 1331107     -318.8100   196      -51.0000     -362.2065 94607266  610.21%
2032934 1332754     -265.4758   167      -51.0000     -362.2058 94669472  610.21%
2034589 1334098     -153.0000    81      -51.0000     -362.2021 94746572  610.20%
2036138 1334328     -243.3282   168      -51.0000     -362.2021 94751540  610.20%
Elapsed time = 5053.58 sec. (3070737.59 ticks, tree = 134474.79 MB, solutions = 37)
Nodefile size = 132323.41 MB (115713.57 MB after compression)
2038712 1333925      -78.5139    50      -51.0000     -362.2021 94744505  610.20%
2040376 1337795    infeasible            -51.0000     -362.1926 94873080  610.18%
2042249 1338711      -95.0000    53      -51.0000     -362.1918 94889167  610.18%
2043289 1339688     -196.9467   171      -51.0000     -362.1918 94930297  610.18%
2044354 1340831     -339.2202   210      -51.0000     -362.1918 94959160  610.18%
2045538 1341759     -316.6392   222      -51.0000     -362.1891 94978591  610.17%
2047212 1344458     -298.5127   183      -51.0000     -362.1891 95116161  610.17%
2048192 1343500     -315.8810   205      -51.0000     -362.1891 95075051  610.17%
2050162 1346617     -258.7810   146      -51.0000     -362.1891 95248518  610.17%
2052107 1347065     -209.5024   121      -51.0000     -362.1834 95285696  610.16%
Elapsed time = 5113.04 sec. (3108900.99 ticks, tree = 135743.20 MB, solutions = 37)
Nodefile size = 133587.80 MB (116827.78 MB after compression)
2054327 1347767     -179.1118   105      -51.0000     -362.1834 95328232  610.16%
2056734 1350306     -355.7437   324      -51.0000     -362.1701 95403631  610.14%
2057895 1349123     -285.9940   159      -51.0000     -362.1701 95387785  610.14%
2059298 1353824     -177.2253   104      -51.0000     -362.1701 95512857  610.14%
2061571 1354213     -235.3818   137      -51.0000     -362.1701 95517218  610.14%
2062721 1354490     -178.5830   101      -51.0000     -362.1701 95521973  610.14%
2063887 1354683     -359.1123   335      -51.0000     -362.1619 95552808  610.12%
```

```
2066171 1357304     -216.6867   128      -51.0000     -362.1588 95666338  610.12%
2068842 1358733     -338.9059   219      -51.0000     -362.1540 95690539  610.11%
2071197 1359079     -151.0000    86      -51.0000     -362.1505 95694410  610.10%
Elapsed time = 5183.43 sec. (3147063.12 ticks, tree = 137247.59 MB, solutions = 37)
Nodefile size = 135065.62 MB (118120.50 MB after compression)
2073960 1362024    infeasible            -51.0000     -362.1492 95770534  610.10%
2076419 1362562     -356.2101   269      -51.0000     -362.1458 95796757  610.09%
2078532 1365651     -229.5769   161      -51.0000     -362.1441 95842208  610.09%
2080519 1367251      -81.0000    42      -51.0000     -362.1406 95880610  610.08%
2082831 1367594     -215.7704   129      -51.0000     -362.1361 95886294  610.07%
2085431 1371304     -165.5000    93      -51.0000     -362.1349 95986118  610.07%
2087706 1371516     -311.5010   186      -51.0000     -362.1292 95993806  610.06%
2090838 1372474     -196.4747   136      -51.0000     -362.1266 96028276  610.05%
2093888 1376175     -268.9368   163      -51.0000     -362.1222 96150851  610.04%
2097037 1376513      -93.0000    48      -51.0000     -362.1195 96156174  610.04%
Elapsed time = 5252.06 sec. (3185223.84 ticks, tree = 139227.82 MB, solutions = 37)
Nodefile size = 137044.02 MB (119868.56 MB after compression)
2099977 1377822     -309.5230   191      -51.0000     -362.1194 96195538  610.04%
2102737 1383997     -216.9528   122      -51.0000     -362.1141 96313606  610.03%
2105386 1382784     -357.4801   259      -51.0000     -362.1109 96296349  610.02%
2107072 1384958     -243.3201   190      -51.0000     -362.1080 96353624  610.02%
2109715 1389908      -91.0000    41      -51.0000     -362.1018 96431278  610.00%
2112892 1389386     -237.2620   142      -51.0000     -362.1014 96428949  610.00%
2116344 1392877      -76.0000    37      -51.0000     -362.0952 96518047  609.99%
2119601 1396055     -239.8675   163      -51.0000     -362.0902 96571138  609.98%
2122701 1397588     -162.0000    92      -51.0000     -362.0878 96597500  609.98%
2125585 1399419     -107.0000    56      -51.0000     -362.0837 96623631  609.97%
Elapsed time = 5323.57 sec. (3223386.22 ticks, tree = 142291.72 MB, solutions = 37)
Nodefile size = 140136.28 MB (122587.56 MB after compression)
2127637 1401788      -98.9772    55      -51.0000     -362.0837 96673819  609.97%
2129462 1403019     -101.0000    53      -51.0000     -362.0777 96689106  609.96%
2130967 1403384     -180.0312   103      -51.0000     -362.0736 96694336  609.95%
2132398 1407650     -249.8456   150      -51.0000     -362.0716 96832474  609.94%
2134190 1407911     -259.4266   153      -51.0000     -362.0716 96840144  609.94%
2136287 1409592     -347.6216   223      -51.0000     -362.0716 96926465  609.94%
2138800 1410407     -107.4540    54      -51.0000     -362.0673 96963154  609.94%
2140533 1410269     -356.8189   314      -51.0000     -362.0623 96948737  609.93%
2141817 1413348     -314.1180   205      -51.0000     -362.0608 97027902  609.92%
2143712 1415198     -361.9409   378      -51.0000     -362.0608 97076664  609.92%
```

```
Elapsed time = 5387.73 sec. (3261572.73 ticks, tree = 144059.10 MB, solutions = 37)
Nodefile size = 141929.99 MB (124151.38 MB after compression)
2145303 1415470     -243.6396   140       -51.0000     -362.0548 97110721  609.91%
2147224 1415864     -346.9044   241       -51.0000     -362.0548 97087785  609.91%
2149106 1420398     -353.5467   272       -51.0000     -362.0502 97254799  609.90%
2151211 1420743     -195.9210   100       -51.0000     -362.0502 97260086  609.90%
2153737 1421083     -290.3449   215       -51.0000     -362.0502 97264392  609.90%
2155994 1424276     -173.5964    95       -51.0000     -362.0502 97359502  609.90%
2157424 1423832     -188.4168   116       -51.0000     -362.0502 97352625  609.90%
2158038 1425742     -231.6470   143       -51.0000     -362.0502 97404097  609.90%
2159500 1428123     -166.8025   112       -51.0000     -362.0502 97507292  609.90%
2161270 1427691     -233.3973   129       -51.0000     -362.0502 97484141  609.90%
Elapsed time = 5455.78 sec. (3299734.67 ticks, tree = 145843.98 MB, solutions = 37)
Nodefile size = 143666.89 MB (125689.91 MB after compression)
2163098 1428744     -310.5486   196       -51.0000     -362.0502 97518331  609.90%
2164625 1429691      -72.0000    29       -51.0000     -362.0502 97530450  609.90%
2166592 1430389     -262.9791   183       -51.0000     -362.0502 97612273  609.90%
2168915 1431725     -356.9467   343       -51.0000     -362.0502 97621871  609.90%
2170713 1434358     -258.5424   166       -51.0000     -362.0502 97704062  609.90%
2172463 1434714     -357.2590   274       -51.0000     -362.0502 97708705  609.90%
2174588 1437891     -344.3184   227       -51.0000     -362.0284 97794992  609.86%
2176317 1438251     -145.9176    80       -51.0000     -362.0284 97800479  609.86%
2177202 1438198     -333.6357   210       -51.0000     -362.0284 97815908  609.86%
2179165 1439916     -353.4805   424       -51.0000     -362.0284 97872104  609.86%
Elapsed time = 5521.06 sec. (3337907.15 ticks, tree = 147605.70 MB, solutions = 37)
Nodefile size = 145495.21 MB (127311.62 MB after compression)
2181324 1440866     -283.2540   176       -51.0000     -362.0284 97891679  609.86%
2182556 1442766     -158.4380    82       -51.0000     -362.0284 97941562  609.86%
2184500 1444493     -314.4764   222       -51.0000     -362.0284 97994623  609.86%
2186406 1444801     -224.1898   124       -51.0000     -362.0284 98013376  609.86%
2188871 1447973     -339.4077   214       -51.0000     -362.0284 98109830  609.86%
2190940 1449999     -290.2922   199       -51.0000     -361.9977 98233021  609.80%
2193520 1449073     -361.5637   435       -51.0000     -361.9977 98128061  609.80%
2196434 1451931     -314.6463   224       -51.0000     -361.9971 98276855  609.80%
2199381 1453652     -185.5070    97       -51.0000     -361.9971 98315726  609.80%
2201426 1454807     -117.0000    60       -51.0000     -361.9971 98362893  609.80%
Elapsed time = 5587.16 sec. (3376070.73 ticks, tree = 149537.40 MB, solutions = 37)
Nodefile size = 147385.66 MB (128968.65 MB after compression)
2204276 1456451     -225.5052   131       -51.0000     -361.9971 98391992  609.80%
```

```
2206451 1460380   -271.7723  166   -51.0000   -361.9904 98473773  609.79%
2209077 1462514   -361.1800  374   -51.0000   -361.9904 98527678  609.79%
2212458 1462879   -197.8400  113   -51.0000   -361.9809 98522461  609.77%
2215420 1467461   -259.2272  145   -51.0000   -361.9735 98624285  609.75%
2218387 1468647   -123.6583   67   -51.0000   -361.9723 98654373  609.75%
2221372 1471853   -350.9130  263   -51.0000   -361.9667 98702789  609.74%
2225070 1470218   -121.0000   64   -51.0000   -361.9636 98673690  609.73%
2228119 1471931   -201.6745  126   -51.0000   -361.9572 98699736  609.72%
2230869 1478734   -305.8009  190   -51.0000   -361.9524 98808636  609.71%
Elapsed time = 5661.26 sec. (3414225.98 ticks, tree = 153064.91 MB, solutions = 37)
Nodefile size = 150931.10 MB (132094.45 MB after compression)
2232763 1478343   -189.2024  111   -51.0000   -361.9492 98802610  609.70%
2234988 1480112   -312.4234  187   -51.0000   -361.9440 98828947  609.69%
2237925 1484751   -313.7701  180   -51.0000   -361.9388 98937741  609.68%
2240558 1486010    -87.0000   43   -51.0000   -361.9364 98964759  609.68%
2242539 1487781   -275.2400  187   -51.0000   -361.9309 99031246  609.67%
2245035 1487728   -219.6291  122   -51.0000   -361.9281 99003844  609.66%
2246529 1491934   -179.1228   94   -51.0000   -361.9255 99095848  609.66%
2247954 1491580   -351.5553  243   -51.0000   -361.9245 99089066  609.66%
2249384 1491991   -291.4054  198   -51.0000   -361.9245 99093972  609.66%
2250277 1494816   -344.8796  224   -51.0000   -361.9245 99189716  609.66%
Elapsed time = 5727.78 sec. (3452393.37 ticks, tree = 155438.60 MB, solutions = 37)
Nodefile size = 153292.60 MB (134181.29 MB after compression)
2251810 1495637   -112.0000   58   -51.0000   -361.9219 99235307  609.65%
2252985 1496849   -242.5733  165   -51.0000   -361.9219 99290827  609.65%
2253778 1497620   -345.1575  417   -51.0000   -361.9219 99333352  609.65%
2254166 1498135   -355.5885  305   -51.0000   -361.9157 99318850  609.64%
2254590 1497715   -156.6532   90   -51.0000   -361.9157 99344381  609.64%
2255374 1499614   -341.7492  301   -51.0000   -361.9143 99483056  609.64%
2256612 1499695   -256.9245  148   -51.0000   -361.9143 99461630  609.64%
2258131 1500600   -112.0000   59   -51.0000   -361.9143 99521815  609.64%
2259968 1502063    -74.0000   31   -51.0000   -361.9143 99596909  609.64%
2261589 1501021   -217.7357  145   -51.0000   -361.9143 99544139  609.64%
Elapsed time = 5789.89 sec. (3490642.38 ticks, tree = 156097.56 MB, solutions = 37)
Nodefile size = 153881.77 MB (134701.90 MB after compression)
2263540 1503689   -351.0484  271   -51.0000   -361.9143 99662117  609.64%
2265593 1505294   -257.5113  150   -51.0000   -361.9143 99690177  609.64%
2267732 1505621    -77.0000   31   -51.0000   -361.9143 99694602  609.64%
2269137 1508711    -65.5679   35   -51.0000   -361.9071 99827984  609.62%
```

```
2270876 1509033     -240.1320   134      -51.0000     -361.9071 99832992  609.62%
2272906 1509090     -314.8264   233      -51.0000     -361.9071 99822254  609.62%
2274629 1511601     -189.8173   101      -51.0000     -361.9002 99916173  609.61%
2275232 1511926     -147.0000    73      -51.0000     -361.9002 99933267  609.61%
2276649 1513432    infeasible            -51.0000     -361.9002 99961904  609.61%
2284484 1518423     -347.9256   237      -51.0000     -361.8881 1.00e+08  609.58%
Elapsed time = 5869.03 sec. (3540255.65 ticks, tree = 158053.08 MB, solutions = 37)
Nodefile size = 155868.06 MB (136448.34 MB after compression)
2293888 1523878     -359.4920   234      -51.0000     -361.8779 1.00e+08  609.56%
2300244 1531155     -143.7059    77      -51.0000     -361.8641 1.01e+08  609.54%
2305495 1533878     -312.1851   184      -51.0000     -361.8641 1.01e+08  609.54%
2310737 1538466     -359.9087   375      -51.0000     -361.8504 1.01e+08  609.51%
2319427 1544696     -187.5489   104      -51.0000     -361.8504 1.01e+08  609.51%
2329798 1548090     -351.7499   300      -51.0000     -361.8348 1.01e+08  609.48%
2340901 1560129     -303.0342   183      -51.0000     -361.8223 1.01e+08  609.46%
2352039 1567246     -183.5988   116      -51.0000     -361.8057 1.02e+08  609.42%
2362020 1573455    infeasible            -51.0000     -361.7982 1.02e+08  609.41%
2374073 1581038     -228.1897   133      -51.0000     -361.7858 1.02e+08  609.38%
Elapsed time = 6146.10 sec. (3692873.43 ticks, tree = 166163.23 MB, solutions = 37)
Nodefile size = 163955.13 MB (143560.66 MB after compression)
2383552 1588797     -311.2394   181      -51.0000     -361.7788 1.02e+08  609.37%
2391426 1596592     -100.0000    67      -51.0000     -361.7660 1.02e+08  609.35%
2399501 1604465     -353.4838   253      -51.0000     -361.7523 1.03e+08  609.32%
2406212 1609092     -187.2150   110      -51.0000     -361.7359 1.03e+08  609.29%
2414023 1613458      -99.6122    48      -51.0000     -361.7213 1.03e+08  609.26%
2423894 1621187     -346.7928   202      -51.0000     -361.7141 1.03e+08  609.24%
2432402 1623753     -181.7823    93      -51.0000     -361.7031 1.03e+08  609.22%
2441756 1636254     -339.1537   432      -51.0000     -361.6890 1.03e+08  609.19%
2448558 1638942     -357.1295   284      -51.0000     -361.6797 1.03e+08  609.18%
2454329 1646493     -207.1387   147      -51.0000     -361.6752 1.04e+08  609.17%
Elapsed time = 6408.01 sec. (3845475.54 ticks, tree = 173640.02 MB, solutions = 37)
Nodefile size = 171517.61 MB (150199.52 MB after compression)
2458581 1647298     -162.0000    89      -51.0000     -361.6752 1.04e+08  609.17%
2466444 1654276     -315.4581   198      -51.0000     -361.6752 1.04e+08  609.17%
2470355 1658826     -353.0127   356      -51.0000     -361.6752 1.04e+08  609.17%
2473616 1660657     -169.0000    93      -51.0000     -361.6752 1.04e+08  609.17%
2477627 1664097     -293.9190   163      -51.0000     -361.6752 1.05e+08  609.17%
2482952 1664957     -317.8915   228      -51.0000     -361.6626 1.05e+08  609.14%
2490159 1670626     -299.0124   185      -51.0000     -361.6626 1.05e+08  609.14%
```

```
2496441 1674807     -179.6537   100      -51.0000     -361.6489 1.05e+08  609.12%
2499857 1680158     -360.0926   333      -51.0000     -361.6489 1.05e+08  609.12%
2503644 1682909     -223.7228   137      -51.0000     -361.6489 1.05e+08  609.12%
Elapsed time = 6660.25 sec. (3998105.33 ticks, tree = 177713.50 MB, solutions = 37)
Nodefile size = 175582.00 MB (153769.34 MB after compression)
2508133 1685701     -351.1965   242      -51.0000     -361.6489 1.05e+08  609.12%
2513566 1689957     -315.2063   204      -51.0000     -361.6489 1.06e+08  609.12%
2522621 1692554     -159.2441    88      -51.0000     -361.6054 1.06e+08  609.03%
2531222 1701571     -351.4425   327      -51.0000     -361.6054 1.06e+08  609.03%
2537166 1707313     -344.7554   276      -51.0000     -361.6054 1.06e+08  609.03%
2543854 1710306     -288.1213   179      -51.0000     -361.6054 1.06e+08  609.03%
2548956 1715402     -352.9752   266      -51.0000     -361.6054 1.06e+08  609.03%
2556366 1719215      -90.8929    53      -51.0000     -361.6054 1.07e+08  609.03%
2563936 1724929     -348.9798   269      -51.0000     -361.5820 1.07e+08  608.98%
2572853 1730095     -143.0000    96      -51.0000     -361.5413 1.07e+08  608.90%
Elapsed time = 6920.25 sec. (4150726.32 ticks, tree = 184835.85 MB, solutions = 37)
Nodefile size = 182651.48 MB (160032.23 MB after compression)
2580724 1735982     -348.7664   273      -51.0000     -361.5161 1.07e+08  608.86%
2585129 1742238     -340.2640   247      -51.0000     -361.5073 1.07e+08  608.84%
2592516 1746730     -357.0770   344      -51.0000     -361.4975 1.07e+08  608.82%
2598719 1750962     -323.6565   219      -51.0000     -361.4916 1.08e+08  608.81%
2606882 1756673     -120.0000    64      -51.0000     -361.4748 1.08e+08  608.77%
2611677 1761982     -164.3744    85      -51.0000     -361.4690 1.08e+08  608.76%
2619177 1766883     -178.8411    97      -51.0000     -361.4666 1.08e+08  608.76%
2627954 1770167     -107.0000    47      -51.0000     -361.4526 1.08e+08  608.73%
2635043 1780029     -123.1203    62      -51.0000     -361.4435 1.09e+08  608.71%
2639585 1781709     -314.0933   199      -51.0000     -361.4365 1.09e+08  608.70%
Elapsed time = 7185.81 sec. (4303333.35 ticks, tree = 191557.34 MB, solutions = 37)
Nodefile size = 189428.39 MB (166019.78 MB after compression)
2647726 1786498     -104.0000    54      -51.0000     -361.4335 1.09e+08  608.69%
2653388 1791883      -89.0000    45      -51.0000     -361.4254 1.09e+08  608.68%
2659559 1796095     -248.7363   154      -51.0000     -361.4195 1.09e+08  608.67%
2664920 1800003     -208.3245   115      -51.0000     -361.4124 1.09e+08  608.65%
2671339 1803572     -242.4922   143      -51.0000     -361.4098 1.09e+08  608.65%
2679485 1809454     -163.4830    93      -51.0000     -361.4098 1.10e+08  608.65%
2687816 1818604     -161.0000    82      -51.0000     -361.4098 1.10e+08  608.65%
2692818 1820449     -106.8889    48      -51.0000     -361.3861 1.10e+08  608.60%
2698954 1825943     -120.0000    69      -51.0000     -361.3847 1.10e+08  608.60%
2705641 1829933     -340.4938   220      -51.0000     -361.3663 1.10e+08  608.56%
```

```
Elapsed time = 7443.22 sec. (4455943.64 ticks, tree = 197301.95 MB, solutions = 37)
Nodefile size = 195152.26 MB (171064.80 MB after compression)
2716311 1836247     -164.0000    97      -51.0000     -361.3485 1.11e+08  608.53%
2724612 1841495     -209.1877   122      -51.0000     -361.3366 1.11e+08  608.50%
2736277 1851272     -354.5079   276      -51.0000     -361.3239 1.11e+08  608.48%
2746256 1859680     -304.4639   194      -51.0000     -361.3177 1.11e+08  608.47%
2752715 1865169     -314.2210   188      -51.0000     -361.3065 1.11e+08  608.44%
2760747 1868729     -334.1027   236      -51.0000     -361.2981 1.11e+08  608.43%
2767824 1874686     -358.6653   314      -51.0000     -361.2860 1.12e+08  608.40%
2776708 1879875     -108.5139    58      -51.0000     -361.2798 1.12e+08  608.39%
2780036 1883524     -346.3044   728      -51.0000     -361.2798 1.12e+08  608.39%

GUB cover cuts applied:  2067
Clique cuts applied:  60
Cover cuts applied:  5679
Implied bound cuts applied:  140
Flow cuts applied:  220
Mixed integer rounding cuts applied:  7001
Zero-half cuts applied:  147
Lift and project cuts applied:  28
Gomory fractional cuts applied:  187

Root node processing (before b&c):
Real time             =    0.01 sec. (4.06 ticks)
Parallel b&c, 8 threads:
Real time             = 7674.31 sec. (4597796.80 ticks)
Sync time (average)   = 2890.35 sec.
Wait time (average)   =    0.00 sec.
------------
Total (root+branch&cut) = 7674.31 sec. (4597800.86 ticks)

------------------------------
Iteration 15
Bounds on # of cuts = 8 with [3 3 2]
Error = 49 (out of 100 instances)
Accuracy = 51
Solving time = 127.905276652 min (minutes)
Accumulated time = 209.928617383 min (minutes)
```

```
Solution status code = 111
LB on error =  -261.279772855
Relative objective gap = 6.083917115

Selected variables:
A_AGE (Continuous)
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
------------------------------
main returns 0

<<< main


<<< done
```

Biography

Songkomkrit Chaiyakan was born in Hatyai, Thailand, on August 12, 1991. He had been studying Mathematics and Applied Mathematics-Economics at Brown University, United States of America, from 2011 to 2013. In 2014, he transferred to a university in Thailand and received the Bachelor of Science (B.Sc.) degree in Mathematics from Prince of Songkla University, Thailand, in 2017. The Master of Science (M.Sc.) degree in Applied Mathematics and Computational Science was conferred by Chulalongkorn University, Thailand, in 2020. Currently, he is pursuing the Doctor of Philosophy (Ph.D.) program in Business Analytics and Data Science at National Institute of Development Administration (NIDA), Thailand.

Regarding work experience, he served as a homework grader for two undergraduate-level courses in calculus and microeconomics at Brown University from September 2012 to May 2013. He also worked as an academic officer at Learn Corporation from June 2019 to November 2019. At Chulalongkorn University, he served as a teaching assistant for two graduate-level courses in mathematical programming and real analysis in addition to three undergraduate-level courses in calculus and stochastic processes from January 2018 to April 2020. At National Institute of Development Administration, he assisted professors with their graduate classes in basic programming and database management, applied machine learning, and data streaming and real-time analytics from August 2022 to May 2024.

His research interest is to develop quantitative tools and achieve a breakthrough in finance, optimization, statistics and artificial intelligence (AI). In his spare time, he enjoys tackling unsolvable problems and also proving or providing interesting insights into commonly used, yet partially theoretically substantiated, statements.

PhD Dissertation Draft

ORIGINALITY REPORT

13%	12%	3%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	cps.ipums.org Internet Source	4%
2	Submitted to Maastricht University Student Paper	2%
3	Submitted to Indian School of Business Student Paper	1%
4	ceprdata.org Internet Source	1%
5	blog.adamfurmanek.pl Internet Source	<1%
6	Submitted to St. Petersburg College Student Paper	<1%
7	corpora.tika.apache.org Internet Source	<1%
8	mail.python.org Internet Source	<1%
9	assets.researchsquare.com Internet Source	<1%

10	people.sc.fsu.edu Internet Source	<1 %
11	wonder.cdc.gov Internet Source	<1 %
12	dlr-ve.gitlab.io Internet Source	<1 %
13	github.com Internet Source	<1 %
14	www.census.gov Internet Source	<1 %
15	users.nber.org Internet Source	<1 %
16	discourse.julialang.org Internet Source	<1 %
17	Submitted to Northcentral Student Paper	<1 %
18	www.sipp.census.gov Internet Source	<1 %
19	www.pop.psu.edu Internet Source	<1 %
20	gitter.im Internet Source	<1 %
21	www.ibm.com Internet Source	<1 %

22	Submitted to Ho Chi Minh University of Technology and Education Student Paper	<1 %
23	pandas.pydata.org Internet Source	<1 %
24	Submitted to Eastern University Student Paper	<1 %
25	cuir.car.chula.ac.th Internet Source	<1 %
26	www.coursehero.com Internet Source	<1 %
27	Submitted to University of St Andrews Student Paper	<1 %
28	Submitted to University of Warwick Student Paper	<1 %
29	Hwang, Soo-yeon. "Measuring information appetite: The desire to spend time with information, engaging in consumption, dissemination, and creation of information for personal reasons.", Rutgers The State University of New Jersey - New Brunswick, 2016 Publication	<1 %
30	mlflow.org Internet Source	<1 %

31	www.columbia.edu Internet Source	<1 %
32	Submitted to University of Nottingham Student Paper	<1 %
33	readthedocs.org Internet Source	<1 %
34	Burleigh, Lauryn Michelle. "Beyond Machine Learning: An fMri Domain Adaptation Model for Multi-Study Integration", Louisiana State University and Agricultural & Mechanical College, 2023 Publication	<1 %
35	Submitted to University of Southern California Student Paper	<1 %
36	Yinzi Jin, Zhiyuan Hou, Donglan Zhang. "Determinants of Health Insurance Coverage among People Aged 45 and over in China: Who Buys Public, Private and Multiple Insurance", PLOS ONE, 2016 Publication	<1 %
37	www.slideshare.net Internet Source	<1 %
38	Amparo Urbano, Jose E. Vila. "Computational Complexity and Communication: Coordination in Two-Player Games", Econometrica, 2002 Publication	<1 %

39	Hanoi National University of Education Publication	<1 %
40	Submitted to National Institute of Development Administration Student Paper	<1 %
41	community.openai.com Internet Source	<1 %
42	ipfs.io Internet Source	<1 %
43	maremival.sociales.unam.mx Internet Source	<1 %
44	António Sérgio Faria, Tiago Soares, José Maria Cunha, Zenaida Mourão. "Mutual-benefit of district heating market and network operation for prosumers integration", Energy Sources, Part B: Economics, Planning, and Policy, 2023 Publication	<1 %
45	www.oas.samhsa.gov Internet Source	<1 %
46	Karpuz, Eylem Güzel. "Geometrik metotlar altinda kelime problemi ve sonuçlari.", Balikesir University (Turkey), 2024 Publication	<1 %
47	repositorio.ufsm.br Internet Source	<1 %

48	Thomas M. Cover, Joy A. Thomas. "Elements of Information Theory", Wiley, 2005 Publication	<1 %
49	deepnote.com Internet Source	<1 %
50	Banire, Bilikis Oluwatoyin. "Attentional Model for Detecting Attention in Children with Autism Spectrum Disorder", Hamad Bin Khalifa University (Qatar), 2022 Publication	<1 %
51	Tobias Doeker, Christoph Herold, Johannes M. Eckhardt, Thomas Kürner. "Eavesdropping Measurements for Applications in Office Environments at Low THz Frequencies", IEEE Transactions on Microwave Theory and Techniques, 2023 Publication	<1 %
52	Submitted to Chulalongkorn University Student Paper	<1 %
53	Ederson Schmeing, André Luiz Brun, Ronan Assumpção Silva. "Dynamic selection of classifiers based on complexity measures", 2022 IEEE 34th International Conference on Tools with Artificial Intelligence (ICTAI), 2022 Publication	<1 %
54	Submitted to Intercollege Student Paper	<1 %

55	T. Mariprasath, Kumar Reddy Cheepati, Marco Rivera. "Practical Guide to Machine Learning, NLP, and Generative AI: Libraries, Algorithms, and Applications", River Publishers, 2024 Publication	<1%
56	Submitted to Technological Institute of the Philippines Student Paper	<1%
57	pastel.archives-ouvertes.fr Internet Source	<1%
58	Natasa Kleanthous, Abir Hussain. "Machine Learning in Farm Animal Behavior using Python", CRC Press, 2025 Publication	<1%
59	Syed Mansoor Sarwar, Robert M. Koretsky. "UNIX - The Textbook, Third Edition", Chapman and Hall/CRC, 2019 Publication	<1%
60	Michał Tomasz Jakóbczyk. "Practical Oracle Cloud Infrastructure", Springer Science and Business Media LLC, 2020 Publication	<1%
61	blog.aweimeow.tw Internet Source	<1%
62	Submitted to QA Learning Student Paper	<1%

63	Stefan Nickel, Claudius Steinhardt, Hans Schlenker, Wolfgang Burkart. "Decision Optimization with IBM ILOG CPLEX Optimization Studio", Springer Science and Business Media LLC, 2022 Publication	<1 %
64	ebin.pub Internet Source	<1 %
65	www.velosecure.com Internet Source	<1 %
66	Bryan J. Lynch, Lorcan A. O'Tuama, S. Ted Treves, Mohamad Mikati, Gregory L. Holmes. "Correlation of99mTc-HMPAO SPECT with EEG monitoring: prognostic value for outcome of epilepsy surgery in children", Brain and Development, 1995 Publication	<1 %
67	Daoce Wang, Jesus Pulido, Pascal Grosset, Jiannan Tian et al. "AMRIC: A Novel In Situ Lossy Compression Framework for Efficient I/O in Adaptive Mesh Refinement Applications", Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis, 2023 Publication	<1 %
68	Submitted to The University of Memphis Student Paper	

<1%

69	digital.library.txstate.edu Internet Source	<1%
70	docs.oracle.com Internet Source	<1%
71	Submitted to University College London Student Paper	<1%
72	www.bls.gov Internet Source	<1%
73	www.gams.com Internet Source	<1%
74	Arfan, Amit Zubier. "On the Topic of Market Making Models: Applying and Calibrating with Stochastic Volatility and Limit Order Book Data", The University of Manchester (United Kingdom) Publication	<1%
75	Durden, Tracie Elizabeth. "The incorporation of Hispanics into the United States health system considering the roles of nativity, duration, and citizenship: A case of acculturation?", Proquest, 20111109 Publication	<1%
76	Ramachandra, Arjun Kodagehalli. "Towards Tightness with Pairwise Independence,	<1%

Extremal Dependence and Robust Satisficing Using Linear and Conic Duality", National University of Singapore (Singapore), 2022
Publication

77	Submitted to University of Glasgow Student Paper	<1%
78	stats.stackexchange.com Internet Source	<1%
79	(11-6-03) http://207.113.108.248/data/progs/cps/cpsmar99.sas Internet Source	<1%
80	Leite, Joana Catarina Santos. "A Machine Learning Approach to Determine Stellar Atmospheric Parameters Using Spectral Data", Universidade do Porto (Portugal), 2024 Publication	<1%
81	blog.csdn.net Internet Source	<1%
82	dspace.mit.edu Internet Source	<1%
83	Submitted to Higher Education Commission Pakistan Student Paper	<1%
84	Li, Yongqing. "Development of as-manufactured CAD model for the concept of "Product DNA"", Proquest, 20111003 Publication	<1%

85	Thomas Christian Gasser. "Chapter 243 Damage and Failure of the Vascular Wall", Springer Science and Business Media LLC, 2020 Publication	<1%
86	Submitted to University of Westminster Student Paper	<1%
87	alibabatech.medium.com Internet Source	<1%
88	flask.frankway.net Internet Source	<1%
89	learnubuntu.com Internet Source	<1%
90	linuxize.com Internet Source	<1%
91	robocup.ethz.ch Internet Source	<1%
92	pypi.org Internet Source	<1%
93	www.ddialliance.org Internet Source	<1%
94	www.tutorialspoint.com Internet Source	<1%
95	123dok.net Internet Source	<1%

96	Clogg, Clifford C., Scott R. Eliason, and Robert J. Wahl. "Labor-Market Experiences and Labor-Force Outcomes", American Journal of Sociology, 1990. Publication	<1 %
97	Submitted to Georgia Institute of Technology Main Campus Student Paper	<1 %
98	S.K. Mitra. "Design of optimal orthogonal tree-structured filter banks", 42nd Midwest Symposium on Circuits and Systems (Cat No 99CH36356) MWSCAS-99, 2000 Publication	<1 %
99	businessanalyticsnida.wordpress.com Internet Source	<1 %
100	cphs.healthrepository.org Internet Source	<1 %
101	proposalspace.com Internet Source	<1 %
102	www.kianmeng.org Internet Source	<1 %
103	www.nber.org Internet Source	<1 %
104	Dirk P. Kroese, Zdravko I. Botev, Thomas Taimre, Radislav Vaisman. "Data Science and	<1 %

Machine Learning - Mathematical and Statistical Methods", CRC Press, 2019
Publication

105 Zakarya Oubrahim, Vincent Choqueuse, Yassine Amirat, Mohamed El Hachemi Benbouzid. "Disturbances Classification Based on a Model Order Selection Method for Power Quality Monitoring", IEEE Transactions on Industrial Electronics, 2017 <1 %
Publication

106 scholarworks.alaska.edu <1 %
Internet Source

107 stackoverflow.com <1 %
Internet Source

108 texdoc.org <1 %
Internet Source

109 www.greaterdandenong.vic.gov.au <1 %
Internet Source

110 www.kansascityfed.org <1 %
Internet Source

111 www.schroders.com <1 %
Internet Source

112 xtreemos.eu <1 %
Internet Source

113 "SNAREs", Springer Science and Business Media LLC, 2025 <1 %

Publication

114	Daniel James Szelogowski. "Deep Learning for Musical Form: Recognition and Analysis", Thesis Commons, 2022 Publication	<1%
115	Eva Kočar, Sonja Katz, Žiga Pušnik, Cene Skubic et al. "Integrative protocol for quantifying cholesterol-related sterols in human serum samples and building decision support systems", STAR Protocols, 2024 Publication	<1%
116	Hoff, Randy . "Clustering-based optimal consultant routing and assignment", Proquest, 2012. Publication	<1%
117	Marius Nagy, Selim G. Akl. "Quantum computation and quantum information†", International Journal of Parallel, Emergent and Distributed Systems, 2006 Publication	<1%
118	Nord, Mark, and Kathleen Romig. "Hunger in the Summer : Seasonal food insecurity and the National School Lunch and Summer Food Service programs", Journal of Children and Poverty, 2006. Publication	<1%
119	Tongqi Zhang. "Construction of Biorthogonal Compactly Supported Vector-Valued	<1%

Wavelets", 2008 Fourth International Conference on Natural Computation, 10/2008
Publication

120	Xia Cui, Wolfgang Karl Härdle, Lixing Zhu. "The EFM approach for single-index models", The Annals of Statistics, 2011 Publication	<1 %
121	Zhou, Ping. "On the irrationality of a certain multivariate infinite product", Quaestiones Mathematicae, 2006. Publication	<1 %
122	core.ac.uk Internet Source	<1 %
123	heagit.cosmos.ru Internet Source	<1 %
124	irclogs.ubuntu.com Internet Source	<1 %
125	journals.lww.com Internet Source	<1 %
126	nova.newcastle.edu.au Internet Source	<1 %
127	repositorio.ufes.br Internet Source	<1 %
128	ucf.digital.flvc.org Internet Source	<1 %

129	vdocuments.mx Internet Source	<1 %
130	ww.nber.org Internet Source	<1 %
131	www.fast-trackcities.org Internet Source	<1 %
132	www.marines.mil Internet Source	<1 %
133	www.prhs.sau48.org Internet Source	<1 %
134	"Machine Learning and Knowledge Extraction", Springer Science and Business Media LLC, 2020 Publication	<1 %
135	Fan, Raymond. "Noise, Signal and Information in Models of Stochastic Gene Expression.", University of Toronto (Canada), 2024 Publication	<1 %
136	I. P. Irodova. "Piecewise Polynomial Approximation Methods in the Theory of Nikol'Skiĭ–Besov Spaces", Journal of Mathematical Sciences, 2015 Publication	<1 %
137	Niu, Xiao. "Essays in applied microeconomics", Proquest, 2014.	<1 %

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		