

# PhD Dissertation Draft

*by* Songkomkrit Chaiyakan

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HIGHLY ACCURATE LINEAR CLASSIFIER WITH APPLICATIONS IN HEALTH  
INSURANCE COVERAGE

Songkomkrit Chaiyakan

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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 1  
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 110  
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.

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## Nomenclature

$\tilde{d}$	full dimension of given training instances
$d$	number of both continuous and categorical features of interest
$d_{\text{cat}}$	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
$x_j^i$	value of feature $j$ of instance $x^i$
$y_k^i$	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 $j$
$b_{j,q}$	$q^{\text{th}}$ splitting value on continuous feature $j$
$u_j$	new group labels on categorical feature $j$
$v_{j,x_j^i}$	new group label of instance $x_j^i$ on categorical feature $j$
$B$	number of total decision boxes
$S_\beta$	$\beta^{\text{th}}$ decision box
$\alpha_{j,q}^i$	whether $x_j^i$ 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 $x_j^i$
$l_{j,q}^i$	$\frac{1}{10}\alpha_{j,q}^i(b_{j,q} + m_j)$
$r_{j,q}^i$	$\alpha_{j,q}^i(b_{j,q+1} - m_j)$
$\gamma_\beta^i$	whether instance $x_j^i$ is in decision box $S_\beta$
$\Theta_\beta$	set of most frequent classes in decision box $S_\beta$
$h_\beta$	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, evidently because their performance metrics are not accuracy. As a result, a multiclass box classifier developed from conventional support vector machine (SVM) through the application of 0-1 mixed integer linear programming (MILP) by counting the number of misclassified instances through majority voting will be proposed in the dissertation to ensure maximum accuracy without overfitting simply due to its linearity. 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 without consideration of interrelationship contributing factors, including their groups of values, on coverage types of health insurance in the United States in 2019. The classification model is trained on the entire survey data because in this dissertation all responses collected from different participants are of equal importance and no prediction about future health insurance coverage is made.

### 1.1 Objectives

1. To propose a multiclass box classifier that yields highest training accuracy.
2. To apply the proposed classification method to investigate significant factors, whether continuous or categorical, influencing health insurance coverage.

### 1.2 Limitations

1. Nonlinear classification in addition to logistic regression are beyond the scope of the study because no interaction between health insurance factors is investigated and splitting values on any two factors should be independent.
2. The health insurance sample data only includes Americans. It was collected in 2020 to reflect health insurance coverage for entire calendar year 2019.
3. Despite its high training accuracy, the proposed classifier takes a significantly long training time and requires enormous space to store a branch-and-cut tree. Its approximation algorithm is not developed in this dissertation although mitigating both problems to some extent. Furthermore, only three factors are preselected and investigated with a sample size of 100. Even in this simple circumstance, the model training lasts longer than a day, but the early-exit classifiers are nonetheless more accurate and parsimonious than a Gini-based decision tree.

## 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, 2024a](#)). 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.

A categorical feature can be handled by one-hot encoding. A multiway tree can be transformed into a binary tree by performing the following operation recursively. For a node having more than two successors, its new successor is created by negating the predicate of one of its preexisting successors and becomes the predecessor of the rest. This procedure maintains the decision regions.

### 2.2.2 SelectKBest

The SelectKBest technique ([Scikit-learn, 2024b](#)) serving as univariate feature selection finds top  $K$  features relating to a target variable based on a score function, for example the mutual information for a discrete target in this dissertation. 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 [50](#) 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.** [34](#) 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  $\psi$  is the logarithmic derivative of the gamma function. The mutual information  $I(\mathbf{X}; Y)$  is estimated by averaging  $I_i$  over all training instances.

**Definiton 2.3.** The *gamma function*  $\Gamma$  and *digamma function*  $\psi$  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 box 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. Connect to a cloud virtual machine using secure shell (SSH) and install Python from source as well as CPLEX.
4. Illustrate the use of the proposed classification method on the health insurance dataset.
5. Compare multiple facets of results with the use of a decision tree.
6. Back up the scripts and results to Oracle Cloud Infrastructure (OCI) Object Storage.
7. Publish the project to GitHub.

#### 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)<sup>113</sup> 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 `icacls` 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 ${Env:USERNAME}:F Administrators:F SYSTEM:F ^
    Everyone:F
attrib +h <key>
icacls <key> /remove ${Env:USERNAME} Administrators SYSTEM ^
    Everyone
icacls <key> /deny "${Env:USERNAME}:(WD,AD,WA,WEA,DE,WDAC,WO)" ^
```

```

"Administrators:(WD,AD,WA,WEA,DE,WDAC,WO)"
icacls <key> /grant ${Env:USERNAME}: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	63 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)
WO	Write owner (take ownership)

### 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 10 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 in this dissertation 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 <sup>86</sup> [GNU Compiler Collection \(GCC\)](#) and [Clang/Low Level Virtual Machine \(LLVM\)](#). This dissertation chooses <sup>88</sup> 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
#ifndef _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
};
#endif _MSC_VER
__pragma(warning(pop))
#endif
```

```

7
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 {
7
    // 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))

59
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.

```

7 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));

```

```

#ifndef 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);
7 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. It is entirely separate from the latest system Python library, shared by multiple native applications, `/usr37/lib/python3.12/config-3.12-x86_64-linux-gnu/libpython3.12.so` which currently points to another symbolic link `/usr/lib/x86_64-linux-gnu/libpython3.12.so.1` and finally to the actual shared library `/usr/lib/x86_64-linux-gnu/libpython3.12.so.1.0`, of which all interfaces remain unchanged (interface version 1) and the library source code is unmodified (revision 0).

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 `gprof` 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 consumption, 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_embedded.py` and sets a timeout of 5 minutes.

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

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 require 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
<code>BZIP2_[LIBS CFLAGS]</code>	<code>libbz2</code>	<code>bz2</code>	<code>libbz2-dev</code>
<code>CURSES_[LIBS CFLAGS]</code>	<code>libncurses</code>	<code>curses</code>	<code>libncurses-dev</code>
<code>GDBM_[LIBS CFLAGS]</code>	<code>gdbm</code>		<code>libgdbm-compat-dev</code>
<code>LIBB2_[LIBS CFLAGS]</code>	<code>libb2</code>	<code>hashlib</code>	<code>libb2-dev</code>
<code>LIBEDIT_[LIBS CFLAGS]</code>	<code>libedit</code>	<code>readline</code>	<code>libreadline-dev</code>
<code>LIBFFI_[LIBS CFLAGS]</code>	<code>libffi</code>	<code>ctypes</code>	<code>libffi-dev</code>
<code>LIBMPDEC_[LIBS CFLAGS]</code>	<code>libmpdec</code>	<code>decimal</code>	
<code>LIBLZMA_[LIBS CFLAGS]</code>	<code>liblzma</code>	<code>lzma</code>	<code>liblzma-dev</code>
<code>LIBREADLINE_[LIBS CFLAGS]</code>	<code>libreadline</code>	<code>readline</code>	<code>libreadline-dev</code>

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

Environment Variables	Library	Module	APT Package
LIBSQLITE3_[LIBS CFLAGS]	sqlite3	sqlite3	sqlite3-dev
LIBUUID_[LIBS CFLAGS]	uuid	uuid	uuid-dev
PANEL_[LIBS CFLAGS]	panel	curses.panel	libpanel-dev
TCLTK_[LIBS CFLAGS]	TCLTK		tk-dev
ZLIB_[LIBS CFLAGS]	zlib	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 `LD_FLAGS` 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.

```
65
export PATH=<install_dir>/bin:$PATH
export LD_LIBRARY_PATH=<install_dir>/lib:${LD_LIBRARY_PATH}#
export LD_FLAGS="-L<install_dir>/lib $LD_FLAGS"
```

This migration should be made to the Bash configuration file `~/.bashrc`. Deprecation 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.

```
94
$ 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 `58 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<sup>68</sup>

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.

```
[57]
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
<sup>126</sup> <code>git clone</code>	Clean copy
<code>git pull</code>	Update with local changes kept
<code>git reset --hard</code>	Update with local changes discarded
<code>git clean -fdx</code>	Clean with untracked files and directories removed
<code>git push</code>	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>
```

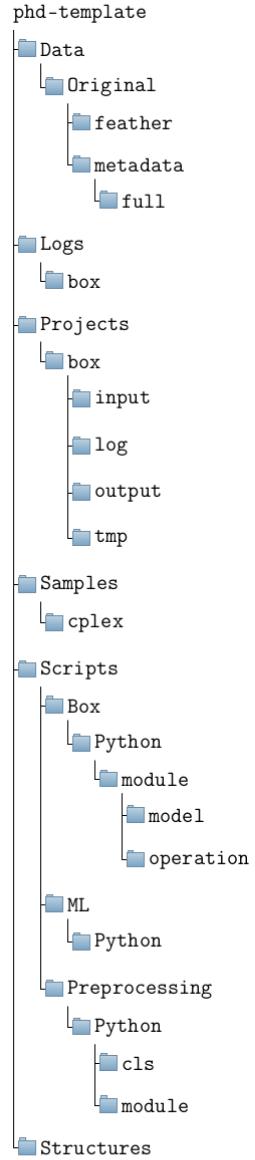
The `<project_dir>` is `Projects/box`. Thanks to its comparative low-resource consumption, using the `oplrun` executable in a terminal is preferred to starting the CPLEX Studio IDE by executing the `oplidle` command. The manual backup of the CPLEX engine log is stored in the directory `Logs/box`. The 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.<sup>137</sup>

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



### 3.5 Health Insurance Dataset

#### 3.5.1 Background

The 2020 <sup>32</sup> 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 <sup>48</sup> 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)

```

1  {
2      "NOW_COV": {
3          "label": "Currently covered by health insurance coverage",

```

```

4      "universe": "All Persons",
5      "type": "Categorical",
6      "role": "Dependent",
7      "topic": "Health insurance",
8      "subtopic": "Any health insurance coverage",
9      "values": {
10         "1": "Yes",
11         "2": "No"
12     }
13 },
14 "NOW_PUB": {
15     "label": "Current public coverage",
16     "universe": "All Persons",
17     "type": "Categorical",
18     "role": "Dependent",
19     "topic": "Health insurance",
20     "subtopic": "Public coverage",
21     "values": {
22         "1": "Yes",
23         "2": "No"
24     }
25 },
26 "NOW_PRIV": {
27     "label": "Current private coverage",
28     "universe": "All Persons",
29     "type": "Categorical",
30     "role": "Dependent",
31     "topic": "Health insurance",
32     "subtopic": "Private coverage",
33     "values": {
34         "1": "Yes",
35         "2": "No"
36     }
37 },
38 "NOW_GRP": {
39     "label": "Any current employment-based coverage",

```

```

40      "universe": "All Persons",
41      "type": "Categorical",
42      "role": "Dependent",
43      "topic": "Health insurance",
44      "subtopic": "Employment-based coverage",
45      "values": {
46          "1": "Yes",
47          "2": "No"
48      },
49  },
50  "NOW_DIR": {
51      "label": "Any current direct-purchase coverage",
52      "universe": "All Persons",
53      "type": "Categorical",
54      "role": "Dependent",
55      "topic": "Health insurance",
56      "subtopic": "Direct-purchase coverage",
57      "values": {
58          "1": "Yes",
59          "2": "No"
60      },
61  },
62  "NOW_MCARE": {
63      "label": "Current Medicare coverage",
64      "universe": "All Persons",
65      "type": "Categorical",
66      "role": "Dependent",
67      "topic": "Health insurance",
68      "subtopic": "Medicare coverage",
69      "values": {
70          "1": "Yes",
71          "2": "No"
72      },
73  },
74  "NOW_MCAID": {
75      "label": "Current Medicaid, PCHIP, or other means-tested coverage",

```

```
76      "universe": "All Persons",
77      "type": "Categorical",
78      "role": "Dependent",
79      "topic": "Health insurance",
80      "subtopic": "Medicaid or other means-tested coverage",
81      "values": {
82          "1": "Yes",
83          "2": "No"
84      }
85 },
86 "NOW_CAID": {
87     "label": "Current Medicaid coverage",
88     "universe": "All Persons",
89     "type": "Categorical",
90     "role": "Dependent",
91     "topic": "Health insurance",
92     "subtopic": "Medicaid coverage",
93     "values": {
94         "1": "Yes",
95         "2": "No"
96     }
97 },
98 "NOW_PCHIP": {
99     "label": "Current PCHIP coverage",
100    "universe": "All Persons",
101    "type": "Categorical",
102    "role": "Dependent",
103    "topic": "Health insurance",
104    "subtopic": "PCHIP coverage",
105    "values": {
106        "1": "Yes",
107        "2": "No"
108    }
109 },
110 "NOW_OTHMT": {
111     "label": "Current other means-tested coverage",
```

```

112     "universe": "All Persons",
113     "type": "Categorical",
114     "role": "Dependent",
115     "topic": "Health insurance",
116     "subtopic": "Other means-tested coverage",
117     "values": {
118       "1": "Yes",
119       "2": "No"
120     }
121   },
122   "NOW_MIL": {
123     "label": "Any current TRICARE coverage",
124     "universe": "All Persons",
125     "type": "Categorical",
126     "role": "Dependent",
127     "topic": "Health insurance",
128     "subtopic": "TRICARE coverage",
129     "values": {
130       "1": "Yes",
131       "2": "No"
132     }
133   },
134   "NOW_CHAMPVA": {
135     "label": "Current CHAMPVA coverage",
136     "universe": "All Persons",
137     "type": "Categorical",
138     "role": "Dependent",
139     "topic": "Health insurance",
140     "subtopic": "CHAMPVA coverage",
19
141     "values": {
142       "1": "Yes",
143       "2": "No"
144     }
145   },
146   "NOW_VACARE": {
147     "label": "Current VACARE coverage",

```

```

148     "universe": "All Persons",
149     "type": "Categorical",
150     "role": "Dependent",
151     "topic": "Health insurance",
152     "subtopic": "VACARE coverage",
153     "values": {
154         "1": "Yes",
155         "2": "No"
156     },
157 },
158 "NOW_IHSFLG": {
159     "label": "Current coverage through the Indian Health Service",
160     "universe": "All Persons",
161     "type": "Categorical",
162     "role": "Dependent",
163     "topic": "Health insurance",
164     "subtopic": "Indian Health Service coverage",
165     "values": {
166         "1": "Yes",
167         "2": "No"
168     }
169 }
170 }
```

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

```

1  {
2      "A AGE": {
3          "label": "Age",
4          "universe": "All Persons",
5          "type": "Continuous",
6          "role": "Independent",
7          "topic": "Demographics",
8          "subtopic": "Individual characteristics",
9          "values": {
```

```

10         "00-79": "0-79 years of age",
11         "80": "80-84 years of age",
12         "85": "85+ years of age"
13     },
14 },
15 "A_EXPRRP": {
16     "label": "Expanded relationship code",
17     "universe": "All Persons",
18     "type": "Categorical",
19     "role": "Independent",
20     "topic": "Demographics",
21     "subtopic": "Individual characteristics",
22     {
23         "1": "Reference person with relatives",
24         "2": "Reference person without relatives",
25         "3": "Husband",
26         "4": "Wife",
27         "5": "Own child",
28         "7": "Grandchild",
29         "8": "Parent",
30         "9": "Brother/sister",
31         "10": "Other relative",
32         "11": "Foster child",
33         "12": "Nonrelative with relatives",
34         "13": "Partner/roommate",
35         "14": "Nonrelative without relatives"
36     },
37 },
38 "A_FAMTYP": {
39     "label": "Family type",
40     "universe": "All Persons",
41     "type": "Categorical",
42     "role": "Independent",
43     "topic": "Demographics",
44     "subtopic": "Individual characteristics",
45     "values": {

```

```

46     "1": "Primary family",
47     "2": "Nonfamily householder",
48     "3": "Related subfamily",
49     "4": "Unrelated subfamily",
50     "5": "Secondary individual"
51   ],
52 },
53 "A_HGA": {
54   "label": "Educational attainment",
55   "universe": "All Persons",
56   "type": "Categorical",
57   "role": "Independent",
58   "topic": "Demographics",
59   "subtopic": "Individual characteristics",
60   "values": [
61     "0": "Children",
62     "31": "Less than 1st grade",
63     "32": "1st,2nd,3rd,or 4th grade",
64     "33": "5th or 6th grade",
65     "34": "7th and 8th grade",
66     "35": "9th grade",
67     "36": "10th grade",
68     "37": "11th grade",
69     "38": "12th grade no diploma",
70     "39": "High school graduate - high school diploma or equivalent
71   ",
72     "40": "Some college but no degree",
73     "41": "Associate degree in college - occupation/vocation
74       program",
75     "42": "Associate degree in college - academic program",
76     "43": "Bachelor's degree (for example: BA,AB,BS)",
77     "44": "Master's degree (for example: MA,MS,MENG,MED,MSW, MBA)",
78     "45": "Professional school degree (for example: MD,DDS,DVM,LLB,
79       JD)",
80     "46": "Doctorate degree (for example: PHD,EDD)"
81   }

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```

79     },
80     "A_MARITL": {
81       "label": "Marital status",
82       "universe": "All Persons",
83       "type": "Categorical",
84       "role": "Independent",
85       "topic": "Demographics",
86       "subtopic": "Individual characteristics",
87       "values": {
88         "1": "Married - civilian spouse present",
89         "2": "Married - AF spouse present",
90         "3": "Married - spouse absent (exc.separated)",
91         "4": "Widowed",
92         "5": "Divorced",
93         "6": "Separated",
94         "7": "Never married"
95       }
96     },
97     "A_PFREL": {
98       "label": "Primary family relationship",
99       "universe": "All Persons",
100      "type": "Categorical",
101      "role": "Independent",
102      "topic": "Demographics",
103      "subtopic": "Individual characteristics",
104      "values": {
105        "0": "Not in primary family",
106        "1": "Husband",
107        "2": "Wife",
108        "3": "Own child",
109        "4": "Other relative",
110        "5": "Unmarried reference person"
111      }
112    },
113    "A_SEX": {
114      "label": "Sex",

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```
115 "universe": "All Persons",
116 "type": "Categorical",
117 "role": "Independent",
118 "topic": "Demographics",
119 "subtopic": "Individual characteristics",
120 "values": {
121     "1": "Male",
122     "2": "Female"
123 }
124 },
125 "P_STAT": {
126     "label": "Status of person identifier",
127     "universe": "All Persons",
128     "type": "Categorical",
129     "role": "Independent",
130     "topic": "Demographics",
131     "subtopic": "Individual characteristics",
132     "1": {
133         "1": "Civilian 15+",
134         "2": "Armed forces",
135         "3": "Children 0-14"
136     }
137 },
138 "PEAFEVER": {
139     "label": "Did you ever serve on active duty in the U.S. Armed Forces?",
140     "universe": "A AGE greater than or equal to 17",
141     "type": "Categorical",
142     "role": "Independent",
143     "topic": "Demographics",
144     "subtopic": "Individual characteristics",
145     "values": {
146         "-1": "Not in universe",
147         "1": "Yes",
148         "2": "No"
149     }
150 }
```

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150     },
151
152     "PEDISDRS": {
153         "label": "Does...have difficulty dressing or bathing?",
154         "universe": "PRPRTYP = 2",
155         "type": "Categorical",
156         "role": "Independent",
157         "topic": "Demographics",
158         "subtopic": "Individual characteristics",
159         "values": {
160             "-1": "Not in universe",
161             7: "Yes",
162             "1": "No"
163         }
164     },
165
166     "PEDISEAR": {
167         "label": "Is...deaf or does ...have serious difficulty hearing?",
168         "universe": "PRPRTYP = 2",
169         "type": "Categorical",
170         "role": "Independent",
171         "topic": "Demographics",
172         "subtopic": "Individual characteristics",
173         "values": {
174             "-1": "Not in universe",
175             16: "Yes",
176             "1": "No"
177         }
178     },
179     "PEDISEYE": {
180         "label": "Is...blind or does...have serious difficulty seeing even
181             when wearing glasses?",
182         "universe": "PRPRTYP = 2",
183         "type": "Categorical",
184         "role": "Independent",
185         "topic": "Demographics",
186         "subtopic": "Individual characteristics",
187         "values": {
188

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185         "-1": "Not in universe",
186         "1": "Yes",
187         "2": "No"
188     },
189 },
190 "PEDISOUT": {
191     "label": "Because of a physical, mental, or emotional condition,
192     does...have difficulty doing errands along such as visiting a
193     doctor's office or shopping?",
194     "universe": "PRPERTYP = 2",
195     "type": "Categorical",
196     "role": "Independent",
197     "topic": "Demographics",
198     "subtopic": "Individual characteristics",
199     "values": {
200         "-1": "Not in universe",
201         "1": "Yes",
202         "2": "No"
203     },
204     "label": "Does...have serious difficulty Walking or climbing stairs
205     ?",
206     "universe": "PRPERTYP = 2",
207     "type": "Categorical",
208     "role": "Independent",
209     "topic": "Demographics",
210     "subtopic": "Individual characteristics",
211     "values": {
212         "-1": "Not in universe",
213         "1": "Yes",
214         "2": "No"
215     },
216     "label": "Does...have serious difficulty Walking or climbing stairs
217     ?",
218     "universe": "PRPERTYP = 2",
219     "type": "Categorical",
220     "role": "Independent",
221     "topic": "Demographics",
222     "subtopic": "Individual characteristics",
223     "values": {
224         "-1": "Not in universe",
225         "1": "Yes",
226         "2": "No"
227     }
228 },
229 "PEDISPHY": {
230     "label": "Does...have serious difficulty Walking or climbing stairs
231     ?",
232     "universe": "PRPERTYP = 2",
233     "type": "Categorical",
234     "role": "Independent",
235     "topic": "Demographics",
236     "subtopic": "Individual characteristics",
237     "values": {
238         "-1": "Not in universe",
239         "1": "Yes",
240         "2": "No"
241     }
242 },
243 "PEDISREM": {
244     "label": "Does...have serious difficulty Walking or climbing stairs
245     ?",
246     "universe": "PRPERTYP = 2",
247     "type": "Categorical",
248     "role": "Independent",
249     "topic": "Demographics",
250     "subtopic": "Individual characteristics",
251     "values": {
252         "-1": "Not in universe",
253         "1": "Yes",
254         "2": "No"
255     }
256 }

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217     "label": "Because of a physical, mental, or emotional condition,  

218         does...have serious difficulty concentrating, remembering, or  

219         making decisions?",  

220     "universe": "PRPRTYP = 2",  

221     "type": "Categorical",  

222     "role": "Independent",  

223     "topic": "Demographics",  

224     "subtopic": "Individual characteristics",  

225     "values": {  

226         "-1": "Not in universe",  

227         16 "1": "Yes",  

228         "2": "No"  

229     },  

230     "PRDISFLG": {  

231         "label": "Does this person have any of these disability conditions?  

232             ",  

233         "universe": "PRPRTYP = 2",  

234         "type": "Categorical",  

235         "role": "Independent",  

236         "topic": "Demographics",  

237         "subtopic": "Individual characteristics",  

238         "values": {  

239             "-1": "Not in universe",  

240             "1": "Yes",  

241             "2": "No"  

242         },  

243         "PRCITSHP": {  

244             "label": "Citizenship group",  

245             "universe": "All persons",  

246             "type": "Categorical",  

247             "role": "Independent",  

248             "topic": "Demographics",  

249             "subtopic": "Individual characteristics",  

250             "values": {  

251                 "-1": "Not in universe",  

252                 "1": "Yes",  

253                 "2": "No"  

254             }

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250     "1": "Native, born in US",
251     "2": "Native, born in PR or US outlying area",
252     "3": "Native, born abroad of US parent(s)",
253     "4": "Foreign born, US cit by naturalization",
254     "5": "Foreign born, not a US citizen"
255   }
256 },
257 "PRDTRACE": {
258   "label": "Race",
259   "universe": "All persons",
260   "type": "Categorical",
261   "role": "Independent",
262   "topic": "Demographics",
263   "subtopic": "Individual characteristics",
264   "values": {
265     "4"
266     "1": "White only",
267     "2": "Black only",
268     "3": "American Indian, Alaskan Native only (AI)",
269     "4": "Asian only",
270     "5": "Hawaiian/Pacific Islander only (HP)",
271     "6": "White-Black",
272     "7": "White-AI",
273     "8": "White-Asian",
274     "9": "White-HP",
275     "10": "Black-AI",
276     "11": "Black-Asian",
277     "12": "Black-HP",
278     "13": "AI-Asian",
279     "14": "AI-HP",
280     "15": "Asian-HP",
281     "16": "White-Black-AI",
282     "17": "White-Black-Asian",
283     "18": "White-Black-HP",
284     "19": "White-AI-Asian",
285     "20": "White-AI-HP",
286     "21": "White-Asian-HP",

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286         "22": "Black-AI-Asian",
287         "23": "White-Black-AI-Asian",
288         "24": "White-AI-Asian-HP",
289         "25": "Other 3 race comb.",
290         "26": "Other 4 or 5 race comb."
291     }
292 },
293 "A_MJIND": {
294     6
295     "label": "Major industry code",
296     "universe": "A_CLSWKR = 1-7",
297     "type": "Categorical",
298     "role": "Independent",
299     1
300     "topic": "Basic CPS items",
301     "subtopic": "Edited labor force items",
302     1
303     "values": {
304         "0": "Not in universe, or children",
305         "1": "Agriculture, forestry, fishing, and hunting",
306         "2": "Mining",
307         "3": "Construction",
308         "4": "Manufacturing",
309         "5": "Wholesale and retail trade",
310         "6": "Transportation and utilities",
311         "7": "Information",
312         "8": "Financial activities",
313         "9": "Professional and business services",
314         "10": "Educational and health services",
315         "11": "Leisure and hospitality",
316         "12": "Other services",
317         "13": "Public administration",
318         "14": "Armed forces"
319     }
320 },
321 "A_MJOCC": {
322     "label": "Major occupation recode",
323     "universe": "A_CLSWKR = 1-7",
324     "type": "Categorical",

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322     "role": "Independent",
323     [1] "topic": "Basic CPS items",
324     "subtopic": "Edited labor force items",
325     [1] "values": {
326         "0": "Not in universe or children",
327         "1": "Management, business, and financial occupations",
328         "2": "Professional and related occupations",
329         "3": "Service occupations",
330         "4": "Sales and related occupations",
331         "5": "Office and administrative support occupations",
332         "6": "Farming, fishing, and forestry occupations",
333         "7": "Construction and extraction occupations",
334         "8": "Installation, maintenance, and repair occupations",
335         "9": "Production occupations",
336         "10": "Transportation and material moving occupations",
337         "11": "Armed forces"
338     }
339 },
340 "PEI01COW": {
341     [12] "label": "Individual class of worker on first job",
342     "universe": "All persons",
343     "type": "Categorical",
344     "role": "Independent",
345     [1] "topic": "Basic CPS items",
346     "subtopic": "Edited labor force items",
347     [1] "values": {
348         "0": "NIU",
349         "1": "Government-federal",
350         "2": "Government-state",
351         "3": "Government - local",
352         "4": "Private, for profit",
353         "5": "Private, nonprofit",
354         "6": "Self-employed, incorporated",
355         "7": "Self-employed, unincorporated",
356         "8": "Without pay"
357     }

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```

358     },
359     "PRDISC": {
360       "label": "Discouraged worker recode",
361       "universe": "All persons",
362       "type": "Categorical",
363       "role": "Independent",
364       "topic": "Basic CPS items",
365       "subtopic": "Edited labor force items",
366       "values": {
367         "0": "NIU",
368         "1": "Discouraged worker",
369         "2": "Conditionally interested",
370         "3": "Not available"
371       }
372     },
373     "PRUNTYPE": {
374       "label": "Individual class of worker on first job",
375       "universe": "All persons",
376       "type": "Categorical",
377       "role": "Independent",
378       "topic": "Basic CPS items",
379       "subtopic": "Edited labor force items",
380       "values": {
381         "0": "NIU",
382         "1": "Job loser/on layoff",
383         "2": "Other job loser",
384         "3": "Temporary job ended",
385         "4": "Job leaver",
386         "5": "Re-entrant",
387         "6": "New-entrant"
388       }
389     },
390     "A_GRSWK": {

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391     "label": "How much does ... usually earn per week at this job  

392         before deductions , subject to topcoding, the higher of either  

393         the amount of item 25a times Item 25c or the actual item 25d  

394         entry will be present",  

395     "universe": "PRERELG=1",  

396     "type": "Continuous",  

397     "role": "Independent",  

398     "topic": "Basic CPS items",  

399     "subtopic": "Edited earnings items",  

400     "values": {  

401         "0": "Not in universe or children or armed forces",  

402         "0001-2885": "Dollar amount"  

403     },  

404     "A_HRLYWK": {  

405         "label": "Is ... paid by the hour on this job?",  

406         "universe": "PRERELG=1",  

407         "type": "Categorical",  

408         "role": "Independent",  

409         "topic": "Basic CPS items",  

410         "subtopic": "Edited earnings items",  

411         "values": {  

412             "0": "Not in universe or children and armed forces",  

413             "1": "Yes",  

414             "2": "No"  

415         },  

416         "A_HRSPAY": {  

417             "label": "How much does ... earn per hour?",  

418             "universe": "A_HRLYWK=1",  

419             "type": "Continuous",  

420             "role": "Independent",  

421             "topic": "Basic CPS items",  

422             "subtopic": "Edited earnings items",  

423             "values": {  

424                 "0": "Not in universe or children or armed forces",  

425             }
426     }
427 }
```

```

424         "0001-9999": "Entry (2 implied decimal places)"
425     }
426 },
427 "PRERELG": {
428     "label": "Earnings eligibility flag",
429     "universe": "All persons",
430     "type": "Categorical",
431     "role": "Independent",
432     "topic": "Basic CPS items",
433     "subtopic": "Edited earnings items",
434     "values": {
435         "0": "Not earnings eligible",
436         "1": "Earnings eligible"
437     }
438 },
439 "A_CIVLF": {
440     "label": "Civilian labor force",
441     "universe": "All persons",
442     "type": "Categorical",
443     "role": "Independent",
444     "topic": "Basic CPS items",
445     "subtopic": "Labor force person recodes",
446     "values": {
447         "0": "Not in universe or children and Armed Forces",
448         "1": "In universe"
449     }
450 },
451 "A_CLSWKR": {
452     "label": "Class of worker",
453     "universe": "PEMLR=1-3 or (PEMLR=4-7 and person worked in the last
454         12 months)",
455     "type": "Categorical",
456     "role": "Independent",
457     "topic": "Basic CPS items",
458     "subtopic": "Labor force person recodes",
459     "values": {

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459         "0": "Not in universe or children and armed forces",
460         "1": "Private",
461         "2": "Federal government",
462         "3": "State government",
463         "4": "Local government",
464         "5": "Self-employed-incorporated",
465         "6": "Self-employed-not incorporated",
466         "7": "Without pay",
467         "8": "Never worked"
468     }
469 },
470 "A_EXPLF": {
471     "label": "Experienced labor force employment status",16
472     "universe": "PEMLR=1-4",
473     "type": "Categorical",
474     "role": "Independent",
475     "topic": "Basic CPS items",
476     "subtopic": "Labor force person recodes",17
477     "values": {
478         "0": "Not in experienced labor force",
479         "1": "Employed",
480         "2": "Unemployed"
481     }
482 },
483 "A_LFSR": {
484     "label": "Labor force status recode",
485     "universe": "All persons",
486     "type": "Categorical",
487     "role": "Independent",
488     "topic": "Basic CPS items",
489     "subtopic": "Labor force person recodes",
490     "values": {
491         "0": "Children or Armed Forces",
492         "1": "Working",
493         "2": "With job, not at work",
494         "3": "Unemployed, looking for work",

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495         "4": "Unemployed, on layoff",
496         "7": "Nelf"
497     },
498 },
499 "A_UNCOV": {
500     [6] "label": "On this job, is ... covered by a union or employee
501         association contract?", "universe": "A_UNMEM=2",
502         "type": "Categorical",
503         "role": "Independent",
504         "topic": "Basic CPS items",
505         "subtopic": "Labor force person recodes",
506         [8] "values": {
507             "0": "Not in universe or children and armed forces",
508             "1": "Yes",
509             "2": "No"
510     },
511 },
512 "A_UNMEM": {
513     [6] "label": "On this job, is ... a member of a labor union or of an
514         employee association similar to a union?", "universe": "PRERELG=1",
515         "type": "Categorical",
516         "role": "Independent",
517         "topic": "Basic CPS items",
518         "subtopic": "Labor force person recodes",
519         [1] "values": {
520             "0": "Not in universe or children and armed forces",
521             "1": "Yes",
522             "2": "No"
523     },
524 },
525 "A_UNTYPE": {
526     "label": "Reason for unemployment",
527     "universe": "A_LFSR=3 or 4",
528     "type": "Categorical",

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529     "role": "Independent",
530     "topic": "Basic CPS items",
531     "subtopic": "Labor force person recodes",
532     "values": {
533       20
534         "0": "Not in universe or children and Armed Forces",
535         "1": "Job loser - on layoff",
536         "2": "Other job loser",
537         "3": "Job leaver",
538         "4": "Re-entrant",
539         "5": "New entrant"
540       }
541     },
542     "A_USLHRS": {
543       "label": "How many hrs per week does ... usually work at this job?"
544       ,
545       "universe": "All persons",
546       "type": "Continuous",
547       "role": "Independent",
548       "topic": "Basic CPS items",
549       "subtopic": "Labor force person recodes",
550       8
551       "values": {
552         "-4": "Hours vary",
553         "-1": "Not in universe",
554         "00": "None, no hours",
555         "01-99": "Entry"
556       }
557     },
558     "A_WKSCH": {
559       6
560       "label": "Labor force by time worked or lost",
561       "universe": "All persons",
562       "type": "Categorical",
563       "role": "Independent",
564       "topic": "Basic CPS items",
565       "subtopic": "Labor force person recodes",
566       "values": {
567         "0": "Not in universe",
568       }
569     }
570   }
571 }
```

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564         "1": "At work",
565         "2": "With job, not at work",
566         "3": "Unemployed, seeks FT",
567         "4": "Unemployed, seeks PT"
568     },
569 },
570 "A_WKSLK": {
571     "label": "Duration of unemployment",
572     "universe": "PEMLR=3 or 4",
573     "type": "Continuous",
574     "role": "Independent",
575     "topic": "Basic CPS items",
576     "subtopic": "Labor force person recodes",
577     values: {
578         "000": "NIU, Children or Armed Forces",
579         "001-999": "Entry"
580     }
581 },
582 "A_WKSTAT": {
583     "label": "Full/part-time status",
584     "universe": "All persons",
585     "type": "Categorical",
586     "role": "Independent",
587     "topic": "Basic CPS items",
588     "subtopic": "Labor force person recodes",
589     values: {
590         "0": "Children or Armed Forces",
591         "1": "Not in labor force",
592         "2": "Full-time schedules",
593         "3": "Part-time for economic reasons, usually FT",
594         "4": "Part-time for non-economic reasons, usually PT",
595         "5": "Part-time for economic reasons, usually PT",
596         "6": "Unemployed FT",
597         "7": "Unemployed PT"
598     }
599 },

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```

600     "PEHRUSLT": {
601         "label": "Hours usually worked last week",
602         "universe": "All persons",
603         "type": "Continuous",
604         "role": "Independent",
605         "topic": "Basic CPS items",
606         "subtopic": "Labor force person recodes",
607         8
608         "values": {
609             "-4": "Hours vary",
610             "-1": "NIU - adult civilian",
611             "000": "NIU - children or Armed Forces or no hours",
612             "1-198": "# of hours"
613         },
614     },
615     "PEMLR": {
616         "label": "Major labor force recode",
617         "universe": "All persons",
618         "type": "Categorical",
619         "role": "Independent",
620         "topic": "Basic CPS items",
621         "subtopic": "Labor force person recodes",
622         1
623         "values": {
624             "0": "NIU",
625             "1": "Employed - at work",
626             "2": "Employed - absent",
627             "3": "Unemployed - on layoff",
628             "4": "Unemployed - looking",
629             "5": "Not in labor force - retired",
630             "6": "Not in labor force - disabled",
631             "7": "Not in labor force - other"
632         },
633     },
634     "PRCOW1": {
635         "label": "Class of worker recode-job 1",
636         "universe": "All persons",
637         "type": "Categorical",

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636     "role": "Independent",
637     "topic": "Basic CPS items",
638     "subtopic": "Labor force person recodes",
639     "values": {
640       "0": "NIU",
641       "1": "Federal govt",
642       "2": "State govt",
643       "3": "Local govt",
644       "4": "Private (incl. self-employed incorp.)",
645       "5": "Self-employed, unincorp.",
646       "6": "Without pay"
647     }
648   },
649   "PRPTREA": {
650     "label": "Detailed reason for part-time",
651     "universe": "Part time workers",
652     "type": "Categorical",
653     "role": "Independent",
654     "topic": "Basic CPS items",
655     "subtopic": "Labor force person recodes",
656     "values": {
657       "0": "NIU",
658       "1": "Usually FT - slack work/business conditions",
659       "2": "Usually FT - seasonal work",
660       "3": "Usually FT - job started/ended during week",
661       "4": "Usually FT - vacation/personal day",
662       "5": "Usually FT - own illness/injury/medical appt",
663       "6": "Usually FT - holiday (religious or legal)",
664       "7": "Usually FT - child care problems",
665       "8": "Usually FT - other fam/pers obligations",
666       "9": "Usually FT - labor dispute",
667       "10": "Usually FT - weather affected job",
668       "11": "Usually FT - school/training",
669       "12": "Usually FT - civic/military duty",
670       "13": "Usually FT - other reason",
671       "14": "Usually PT - slack work/business conditions",

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672         "15": "Usually PT - PT could only find PT work",
673         "16": "Usually PT - seasonal work",
674         "17": "Usually PT - child care problems",
675         "18": "Usually PT - other fam/pers obligations",
676         "19": "Usually PT - health/medical limitations",
677         "20": "Usually PT - school/training",
678         "21": "Usually PT - retired/social security limit on earnings",
679         "22": "Usually PT - workweek<35 hours",
680         "23": "Usually PT - other"
681     }
682 },
683 "PRWKSTAT": {
684     "label": "Full/part-time work status",
685     "universe": "All persons",
686     "type": "Categorical",
687     "role": "Independent",
688     "topic": "Basic CPS items",
689     "subtopic": "Labor force person recodes",
690     "values": {
691         "4": "NIU",
692         "0": "Not in labor force",
693         "2": "FT hours (35+), usually FT",
694         "3": "PT for economic reasons, usually FT",
695         "4": "PT for non-economic reasons, usually FT",
696         "5": "Not at work, usually FT",
697         "6": "PT hrs, usually PT for economic reasons",
698         "7": "PT hrs, usually PT for non-economic",
699         "8": "FT hours, usually PT for economic reasons",
700         "9": "FT hours, usually PT for non-economic reasons",
701         "10": "Not at work, usually part-time",
702         "11": "Unemployed FT",
703         "12": "Unemployed PT"
704     }
705 },
706 "CLWK": {
707     "label": "Longest job class of worker (recode)",

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```
708     "universe": "All persons aged 15+",  
709     "type": "Categorical",  
710     "role": "Independent",  
711     "topic": "Work experience",  
712     "subtopic": "General",  
713     1  
714     "values": {  
715         "0": "Niu",  
716         "1": "Private",  
717         "2": "Government",  
718         "3": "Self-employed",  
719         "4": "Without pay",  
720         "5": "Never worked"  
721     },  
722     "EARNER": {  
723         "label": "Earner status recode",  
724         "universe": "All persons aged 15+",  
725         "type": "Categorical",  
726         "role": "Independent",  
727         "topic": "Work experience",  
728         "subtopic": "General",  
729         "values": {  
730             "0": "Niu",  
731             "1": "Earner",  
732             "2": "Nonearner"  
733         },  
734     },  
735     "HRSWK": {  
736         1  
737         "label": "In the weeks that ... worked how many hours did ...  
738             usually work per week?",  
739         "universe": "WKSWORK > 0",  
740         "type": "Continuous",  
741         "role": "Independent",  
742         "topic": "Work experience",  
743         "subtopic": "General",  
744         "values": {
```

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743         "0": "Niu",
744         "1": "1 hour",
745         "2-98": "2-98 hours",
746         "99": "99 hours plus"
747     }
748 },
749 "LJCW": {
750     "label": "Longest job class of worker",
751     "universe": "WKSWORK > 0",
752     "type": "Categorical",
753     "role": "Independent",
754     "topic": "Work experience",
755     "subtopic": "General",
756     [6]
757     "values": {
758         "0": "Niu",
759         "1": "Private",
760         "2": "Federal",
761         "3": "State",
762         "4": "Local",
763         "5": "Self employed incorporated, yes",
764         "6": "Self employed incorporated, no or farm",
765         "7": "Without pay"
766     }
767 },
768 "NWLKWK": {
769     [6]
770     "label": "How many different weeks was ... looking for work or on
771     layoff?",
772     "universe": "NWLOOK = 1",
773     "type": "Continuous",
774     "role": "Independent",
775     "topic": "Work experience",
776     "subtopic": "General",
777     [6]
778     "values": {
779         "0": "Niu",
780         "1": "1 week",
781         "2-51": "2-51 weeks",
782     }

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778         "52": "52 weeks"
779     },
780 },
781 "NWLOOK": {
782     "label": "Even though ... did not work in 20.. did spend and time
783         trying to find a job or on layoff?",  

784     "universe": "WORKYN = 2",
785     "type": "Categorical",
786     "role": "Independent",
787     "topic": "Work experience",
788     "subtopic": "General",
789     "values": {
790         "0": "Niu",
791         "1": "Yes",
792         "2": "No"
793     }
794 },
795 "PHMEMPRS": {
796     "label": "For how many employers did ... work in 20..? if more than
797         one at same time, only count it as one employer",
798     "universe": "WKSWORK > 0",
799     "type": "Categorical",
800     "role": "Independent",
801     "topic": "Work experience",
802     "subtopic": "General",
803     "values": {
804         "0": "Niu",
805         "1": "One employer",
806         "2": "Two employers",
807         "3": "3 or more employers"
808     }
809 },
810 "RSNNNOTW": {
811     "label": "What was the main reason ... did not work in 20..?",
812     "universe": "WORKYN = 2",
813     "type": "Categorical",

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812     "role": "Independent",
813     "topic": "Work experience",
814     "subtopic": "General",
815     1   "values": {
816       "0": "Niu",
817       "1": "Ill or disabled",
818       "2": "Retired",
819       "3": "Taking care of home",
820       "4": "Going to school",
821       "5": "Could not find work",
822       "6": "Other"
823     },
824   },
825   "WECLW": {
15    "label": "Longest job class of worker (persons 15+)",
826    "universe": "All persons aged 15+",
827    "type": "Categorical",
828    "role": "Independent",
829    "topic": "Work experience",
830    "subtopic": "General",
831    1   "values": {
832      "0": "Not in universe",
833      "1": "Agriculture (Wage and salary)",
834      "2": "Agriculture (Self-employed)",
835      "3": "Agriculture (Unpaid)",
836      "4": "Nonagriculture (Private household",
837      "5": "Nonagriculture (Other private)",
838      "6": "Nonagriculture (Government)",
839      "7": "Nonagriculture (Self-employed)",
840      "8": "Nonagriculture (Unpaid)",
841      "9": "Nonagriculture (Never worked)"
842    },
843  },
844 },
845   "WEWKRS": {
846     "label": "Weeks worked recode",
847     "universe": "All persons aged 15+",

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848     "type": "Categorical",
849     "role": "Independent",
850     "topic": "Work experience",
851     "subtopic": "General",
852     "values": {
853         "0": "Niu",
854         "1": "Full-year worker (Full time)",46
855         "2": "Full-year worker (Part time)",
856         "3": "Part-year worker (Full time)",
857         "4": "Part-year worker (Part time)",
858         "5": "Part-year worker (Nonworker)"
859     }
860 },
861 "WKSWORK": {8
862     "label": "During 20... in how many weeks did ... work even for a few
863         hours? (include paid vacation and sick leave as work)",
864     "universe": "Persons 15+ with WORKYN = 1",
865     "type": "Continuous",
866     "role": "Independent",
867     "topic": "Work experience",
868     "subtopic": "General",1
869     "values": {
870         "0": "Niu",
871         "1": "1 week",
872         "2-51": "2-51 weeks",
873         "52": "52 weeks"
874     }
875 },
876 "WORKYN": {
877     "label": "Did ... work at a job or business at any time during
878         20...?",2
879     "universe": "All persons aged 15+",
880     "type": "Categorical",
881     "role": "Independent",
882     "topic": "Work experience",
883     "subtopic": "General",
884 }
```

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882     "values": {  

883         "0": "Niu",  

884         "1": "Yes",  

885         "2": "No"  

886     },  

887 },  

888 "WRK_CK": {  

889     "label": "Worked last year recode, including temporary and part-  

890     time",  

891     "universe": "All persons aged 15+",  

892     "type": "Categorical",  

893     "role": "Independent",  

894     "topic": "Work experience",  

895     "subtopic": "General",  

896     "values": {  

897         "0": "Niu",  

898         "1": "Yes",  

899         "2": "No"  

900     },  

901 },  

902 "WTEMP": {  

903     "label": "Did ... do any temporary, part-time, or seasonal work  

904     even for a few days during 20..?",  

905     "universe": "WORKYN = 2",  

906     "type": "Categorical",  

907     "role": "Independent",  

908     "topic": "Work experience",  

909     "subtopic": "General",  

910     "values": {  

911         "0": "Niu",  

912         "1": "Yes",  

913         "2": "No"  

914     },  

915     "label": "Wage and salary money earned from other work, Y/N",  


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916     "universe": "All persons aged 15+",
917     "type": "Categorical",
918     "role": "Independent",
919     "topic": "Income",
920     "subtopic": "Earnings", 1
921     "values": {
922         "0": "Niu",
923         "1": "Yes",
924         "2": "No"
925     } }
926 },
927 "ERN_SRCE": { 6
928     "label": "Source of earnings from longest job",
929     "universe": "ERN_YN = 1",
930     "type": "Categorical",
931     "role": "Independent",
932     "topic": "Income",
933     "subtopic": "Earnings", 1
934     "values": {
935         "0": "Niu",
936         "1": "Wage and salary",
937         "2": "Self employment",
938         "3": "Farm self employment",
939         "4": "Without pay"
940     } }
941 },
942 "ERN_VAL": { 4
943     "label": "How much did ... earn from this employer before
944         deductions in 20..? what was ... net earnings from this
945         business/ farm after expenses during 20..?",
946     "universe": "ERN_YN = 1",
947     "type": "Continuous",
948     "role": "Independent",
949     "topic": "Income",
950     "subtopic": "Earnings",
951     "values": {

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950         "0": "None or Niu",
951         "-9,999 - 9,999,999": "Wages & self-employment"
952     },
953 },
954 "ERN_YN": {
955     "label": "Earnings from employer or net earnings from business/
956         farm after expenses from longest job during 20.. ?",
957     "universe": "WORKYN=1 or WTEMP=1",
958     "type": "Categorical",
959     "role": "Independent",
960     "topic": "Income",
961     "subtopic": "Earnings",
962     "values": {
963         "0": "Niu",
964         "1": "Yes",
965         "2": "No"
966     },
967     "FRM_VAL": {
968         "label": "Amount of farm self-employment earnings from secondary
969             source",
970         "universe": "FRMOTR = 1",
971         "type": "Continuous",
972         "role": "Independent",
973         "topic": "Income",
974         "subtopic": "Earnings",
975         "values": {
976             "0": "None or Niu",
977             "-999999-999999": "Farm self employment"
978         },
979         "FRMOTR": {
980             "label": "Receiving farm self-employment from secondary source",
981             "universe": "ERN_OTR = 1",
982             "type": "Categorical",
983             "role": "Independent",

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984     "topic": "Income",
985     "subtopic": "Earnings",
986     "values": {
987         "0": "Niu",
988         "1": "Yes",
989         "2": "No"
990     }
991 },
992 "FRSE_VAL": {
993     "label": "Total amount of farm self-employment earnings",
994     "universe": "ERN_YN=1 or FRMOTR=1",
995     "type": "Continuous",
996     "role": "Independent",
997     "topic": "Income",
998     "subtopic": "Earnings",
999     "values": {
1000         "0": "None or Niu",
1001         "-999999-999999": "Farm self employment"33
1002     }
1003 },
1004 "FRSE_YN": {
1005     "label": "Receiving any farm self-employment",
1006     "universe": "ERN_YN=1 or FRMOTR=1",
1007     "type": "Categorical",
1008     "role": "Independent",
1009     "topic": "Income",
1010     "subtopic": "Earnings",
1011     "values": {
1012         "0": "Niu",
1013         "1": "Yes",
1014         "2": "No"
1015     }
1016 },
1017 "PEARNVAL": {
1018     "label": "Total persons earnings",
1019     "universe": "All persons aged 15+",
```

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1020     "type": "Continuous",
1021     "role": "Independent",
1022     "topic": "Income",
1023     "subtopic": "Earnings",
1024     "values": {
1025       "0": "None;",
1026       "negative amt": "Income (loss);",
1027       "positive amt": "Income"
1028     }
1029   },
1030   "SE_VAL": {
1031     "label": "Amount of own business self-employment earnings from
1032       secondary source",
1033     "universe": "SEOTR = 1",
1034     "type": "Continuous",
1035     "role": "Independent",
1036     "topic": "Income",
1037     "subtopic": "Earnings",
1038     "values": {
1039       "0": "None or niu;",
1040       "-99999-99999": "Own business self employment"
1041     }
1042   },
1043   "SEMP_VAL": {
1044     "label": "Total own business self-employment earnings (combined
1045       amounts in ern-val, if ern-srce=2, and se-val)",
1046     "universe": "ERN_YN=1 or SEOTR=1",
1047     "type": "Continuous",
1048     "role": "Independent",
1049     "topic": "Income",
1050     "subtopic": "Earnings",
1051     "values": {
1052       "0": "None or niu;",
1053       "-99999-99999": "Own business self employment"
1054     }
1055   },

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1054     "SEMP_YN": {
1055         "label": "Receiving own business self-employment, y/n",
1056         "universe": "ERN_YN=1 or SEOTR=1",
1057         "type": "Categorical",
1058         "role": "Independent",
1059         "topic": "Income",
1060         "subtopic": "Earnings",
1061         "values": {
1062             "0": "Niu",
1063             "1": "Yes",
1064             "2": "No"
1065         }
1066     },
1067     "SEOTR": {
1068         "label": "Receiving own business self-employment, y/n",
1069         "universe": "ERN_YN=1 or SEOTR=1",
1070         "type": "Categorical",
1071         "role": "Independent",
1072         "topic": "Income",
1073         "subtopic": "Earnings",
1074         "values": {
1075             "0": "Niu",
1076             "1": "Yes",
1077             "2": "No"
1078         }
1079     },
1080     "WAGEOTR": {
1081         "label": "Receiving wage and salary earnings from other employers,
1082             y/n",
1083         "universe": "ERN_OTR = 1",
1084         "type": "Categorical",
1085         "role": "Independent",
1086         "topic": "Income",
1087         "subtopic": "Earnings",
1088         "values": {
1089             "0": "Niu",

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1089         "1": "Yes",
1090         "2": "No"
1091     },
1092 },
1093 "WS_VAL": {
1094     "label": "Amount of wage and salary earnings from other employers",
1095     "universe": "ERN_OTR = 1",
1096     "type": "Continuous",
1097     "role": "Independent",
1098     "topic": "Income",
1099     "subtopic": "Earnings",
1100     "values": {
1101         "0": "None or niu;",
1102         "1-9999999": "Wage and salary"
1103     }
1104 },
1105 "WSAL_VAL": {
1106     "label": "Total wage and salary earnings (combined amounts in ern-
1107         val, if ern-srce=1, and ws-val)",
1108     "universe": "ERN_YN=1 or WAGEOTR=1",
1109     "type": "Continuous",
1110     "role": "Independent",
1111     "topic": "Income",
1112     "subtopic": "Earnings",
1113     "values": {
1114         "0": "None or niu;",
1115         "1-9999999": "Wage and salary"
1116     }
1117 },
1118 "WSAL_YN": {
1119     "label": "Receiving wage and salary earnings",
1120     "universe": "ERN_YN=1 or WAGEOTR=1",
1121     "type": "Categorical",
1122     "role": "Independent",
1123     "topic": "Income",
1124     "subtopic": "Earnings",

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1124     "values": {
1125         "0": "Niu",
1126         "1": "Yes",
1127         "2": "No"
1128     }
1129 },
1130 "ANN_VAL": {
1131     "label": "Retirement income, annuities amount",
1132     "universe": "ANN_YN = 1",
1133     "type": "Continuous",
1134     "role": "Independent",
1135     "topic": "Income",
1136     "subtopic": "Other income",
1137     "values": {
1138         "-1": "Niu",
1139         "0-999999": "Dollar amount"
1140     }
1141 },
1142 "ANN_YN": {
1143     "label": "Retirement income, annuities, y/n",
1144     "universe": "All Persons aged 15+",
1145     "type": "Categorical",
1146     "role": "Independent",
1147     "topic": "Income",
1148     "subtopic": "Other income",
1149     "values": {
1150         "0": "Niu",
1151         "1": "Yes",
1152         "2": "No"
1153     }
1154 },
1155 "CAP_VAL": {
1156     "label": "Capital gains value",
1157     "universe": "CAP_YN = 1",
1158     "type": "Continuous",
1159     "role": "Independent",

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1160     "topic": "Income",
1161     "subtopic": "Other income",
1162     "values": {
1163         "0": "None or niu",
1164         "1-9999999": "Captial gains amount"
1165     }
1166 },
1167 "CAP_YN": {
1168     "label": "Yes/no answer to 'Did you receive capital gain from your
1169     shares of stock or mutual fund?'",
1170     "universe": "DIV_YN = 1",
1171     "type": "Categorical",
1172     "role": "Independent",
1173     "topic": "Income",
1174     "subtopic": "Other income",
1175     "values": {
1176         "0": "Niu",
1177         "1": "Yes",
1178         "2": "No"
1179     }
1180 },
1181 "DBTN_VAL": {
1182     "label": "Total amount of retirement distributions received (
1183     dst_val1 + dst_val2)",
1184     "universe": "DST_VAL1>0 OR DST_VAL2>0",
1185     "type": "Continuous",
1186     "role": "Independent",
1187     "topic": "Income",
1188     "subtopic": "Other income",
1189     "values": {
1190         "0": "None or niu",
1191         "1-9999999": "Dollar amount"
1192     }
1193 },
1194 "DIS_SC1": {
1195     "label": "What was the source of disability income?",
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1194     "universe": "DIS_YN=1",
1195     "type": "Categorical",
1196     "role": "Independent",
1197     "topic": "Income",
1198     "subtopic": "Other income",
1199     "values": {
1200         "0": "Niu",
1201         "1": "Worker's compensation",
1202         "2": "Company or union disability",
1203         "3": "Federal government disability",
1204         "4": "Us military retirement disability",
1205         "5": "State or local gov't employee disability",
1206         "6": "Us railroad retirement disability",
1207         "7": "Accident or disability insurance",
1208         "8": "Blacklung miners disability",
1209         "9": "State temporary sickness",
1210         "10": "Other or don't know"
1211     }
1212 },
1213 "DIS_SC2": {
1214     "label": "What was the source of disability income?",
1215     "universe": "DIS_YN=1",
1216     "type": "Categorical",
1217     "role": "Independent",
1218     "topic": "Income",
1219     "subtopic": "Other income",
1220     "values": {
1221         "0": "Niu",
1222         "1": "Worker's compensation",
1223         "2": "Company or union disability",
1224         "3": "Federal government disability",
1225         "4": "Us military retirement disability",
1226         "5": "State or local gov't employee disability",
1227         "6": "Us railroad retirement disability",
1228         "7": "Accident or disability insurance",
1229         "8": "Blacklung miners disability",

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1230         "9": "State temporary sickness",
1231         "10": "Other or don't know"
1232     },
1233 },
1234 "DIS_VAL1": {
1235     "label": "How much did ... receive (source type) during 20.. ?",
1236     "universe": "DIS_SC1>0",
1237     "type": "Continuous",
1238     "role": "Independent",
1239     "topic": "Income",
1240     "subtopic": "Other income",
1241     "values": {
1242         "0": "None or niu",
1243         "1-999999": "Disability income"
1244     },
1245 },
1246 "DIS_VAL2": {
1247     "label": "How much did ... receive (source type) during 20.. ?",
1248     "universe": "DIS_SC2>0",
1249     "type": "Continuous",
1250     "role": "Independent",
1251     "topic": "Income",
1252     "subtopic": "Other income",
1253     "values": {
1254         "0": "None or niu",
1255         "1-999999": "Disability income"
1256     },
1257 },
1258 "DIS_YN": {
1259     "label": "Other than social security did ... receive any income in
20.. as a result of health problems?",
1260     "universe": "All Persons aged 15+",
1261     "type": "Categorical",
1262     "role": "Independent",
1263     "topic": "Income",
1264     "subtopic": "Other income",

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1265     "values": {  

1266         "0": "Niu",  

1267         "1": "Yes",  

1268         "2": "No"  

1269     },  

1270 },  

1271 "DIV_VAL": {  

1272     "label": "How much did ... receive in dividends from stocks or  

1273         mutual funds during 20...?",  

1274     "universe": "DIV_YN = 1",  

1275     "type": "Continuous",  

1276     "role": "Independent",  

1277     "topic": "Income",  

1278     "subtopic": "Other income",  

1279     "values": {  

1280         "0": "None or niu",  

1281         "1-999999": "Dividends"  

1282     },  

1283 },  

1284 "DIV_YN": {  

1285     "label": "Did .... receive dividends?",  

1286     "universe": "All Persons aged 15+",  

1287     "type": "Categorical",  

1288     "role": "Independent",  

1289     "topic": "Income",  

1290     "subtopic": "Other income",  

1291     "values": {  

1292         "0": "Niu",  

1293         "1": "Yes",  

1294         "2": "No"  

1295     },  

1296 },  

1297 "DSAB_VAL": {  

1298     "label": "Total amount of disability income received, combined  

1299         amounts in edited sources one and two",  

1300     "universe": "DIS_VAL1>0 OR DIS_VAL2>0",  

1301 }
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1299     "type": "Continuous",
1300     "role": "Independent",
1301     "topic": "Income",
1302     "subtopic": "Other income",
1303     "values": {
1304       "0": "None or niu",
1305       "1-999999": "Disability income"
1306     }
1307   },
1308   "DST_SC1": {
1309     "label": "Retirement income, distribution source 1",
1310     "universe": "DST_VAL1 > 0 and a_age >= 58",
1311     "type": "Categorical",
1312     "role": "Independent",
1313     "topic": "Income",
1314     "subtopic": "Other income",
1315     "values": {
1316       "0": "Niu",
1317       "1": "401k account",
1318       "2": "403b account",
1319       "3": "Roth ira",
1320       "4": "Regular ira",
1321       "5": "Keogh plan",
1322       "6": "Sep plan (simplified employee pension)",
1323       "7": "Other type of retirement account"
1324     }
1325   },
1326   "DST_SC1_YNG": {
1327     "label": "Retirement Distribution source 1, person under age 58",
1328     "universe": "DST_YN_YNG = 1 and a_age < 58",
1329     "type": "Categorical",
1330     "role": "Independent",
1331     "topic": "Income",
1332     "subtopic": "Other income",
1333     "values": {
1334       "0": "Niu",

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1335         "1": "401k account",
1336         "2": "403b account",
1337         "3": "Roth ira",
1338         "4": "Regular ira",
1339         "5": "Keogh plan",
1340         "6": "Sep plan (simplified employee pension)",
1341         "7": "Other type of retirement account"
1342     }
1343 },
1344 "DST_SC2": {
1345     "label": "Retirement income, distribution source 2",
1346     "1"
1347     "universe": "DST_VAL2 > 0 and a_age >= 58",
1348     "type": "Categorical",
1349     "role": "Independent",
1350     "topic": "Income",
1351     "subtopic": "Other income",
1352     "1"
1353     "values": {
1354         "0": "Niu",
1355         "1": "401k account",
1356         "2": "403b account",
1357         "3": "Roth ira",
1358         "4": "Regular ira",
1359         "5": "Keogh plan",
1360         "6": "Sep plan (simplified employee pension)",
1361         "7": "Other type of retirement account"
1362     }
1363 },
1364 "DST_SC2_YNG": {
1365     "label": "Retirement Distribution source 2, person under age 58",
1366     "universe": "DST_VAL_YNG > 0 and a_age < 58",
1367     "type": "Categorical",
1368     "role": "Independent",
1369     "topic": "Income",
1370     "subtopic": "Other income",
1371     "values": {
1372         "0": "Niu",

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1371         "1": "401k account",
1372         "2": "403b account",
1373         "3": "Roth ira",
1374         "4": "Regular ira",
1375         "5": "Keogh plan",
1376         "6": "Sep plan (simplified employee pension)",
1377         "7": "Other type of retirement account"
1378     },
1379 },
1380 "DST_VAL1": {
1381     "label": "Retirement income amount, distribution source 1",
1382     "universe": "DST_SC1 = 1",
1383     "type": "Continuous",
1384     "role": "Independent",
1385     "topic": "Income",
1386     "subtopic": "Other income",
1387     "values": {
1388         "0": "None or niu",
1389         "1- 999,999": "Amount withdrawn or distributed"
1390     },
1391 },
1392 "DST_VAL1_YNG": {
1393     "label": "Retirement Distribution amount 1, under age 58",
1394     "universe": "DST_SC1_YNG = 1",
1395     "type": "Continuous",
1396     "role": "Independent",
1397     "topic": "Income",
1398     "subtopic": "Other income",
1399     "values": {
1400         "0": "None or niu",
1401         "1- 999,999": "Amount withdrawn or distributed"
1402     },
1403 },
1404 "DST_VAL2": {
1405     "label": "Retirement income amount, distribution source 2",
1406     "universe": "DST_SC2 = 1",

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1407     "type": "Continuous",
1408     "role": "Independent",
1409     "topic": "Income",
1410     "subtopic": "Other income",
1411     "values": {
1412       "0": "None or niu",
1413       "1- 999,999": "Amount withdrawn or distributed"
1414     }
1415   },
1416   "DST_VAL2_YNG": {
1417     "label": "Retirement Distribution amount 2, under age 58",
1418     "universe": "DST_SC2_YNG = 1",
1419     "type": "Continuous",
1420     "role": "Independent",
1421     "topic": "Income",
1422     "subtopic": "Other income",
1423     "values": {
1424       "0": "None or niu",
1425       "1- 999,999": "Amount withdrawn or distributed"
1426     }
1427   },
1428   "DST_YN": {
1429     "label": "Retirement income distribution y/n",
1430     "universe": "Persons aged 58 and over (a_age >= 58)",
1431     "type": "Categorical",
1432     "role": "Independent",
1433     "topic": "Income",
1434     "subtopic": "Other income",
1435     "values": {
1436       "0": "Niu",
1437       "1": "Yes",
1438       "2": "No"
1439     }
1440   },
1441   "DST_YN_YNG": {
1442     "label": "Retirement Distribution Recipiency, person under age 58",

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1443     "1": "Persons under age 58 (a_age < 58)",
1444     "type": "Categorical",
1445     "role": "Independent",
1446     "topic": "Income",
1447     "subtopic": "Other income",
1448     "values": {
1449         "0": "Niu",
1450         "1": "Yes",
1451         "2": "No"
1452     }
1453 },
1454 "ED_VAL": {
1455     "1": {
1456         "label": "Total amount of educational assistance received (combined
1457             amounts in pell grant and other educational) assistance during
1458             20.. ?",
1459         "universe": "ED_YN = 1",
1460         "type": "Continuous",
1461         "role": "Independent",
1462         "topic": "Income",
1463         "subtopic": "Other income",
1464         "values": {
1465             "0": "None or niu",
1466             "1- 99,999": "Dollar amount"
1467     }
1468 },
1469 "ED_YN": {
1470     "label": "Did ... receive educational assistance?",
1471     "universe": "All Persons aged 15+",
1472     "type": "Categorical",
1473     "role": "Independent",
1474     "topic": "Income",
1475     "subtopic": "Other income",
1476     "values": {
1477         "0": "Niu",
1478         "1": "Yes",
1479         "2": "No"

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1477     }
1478 },
1479 "FIN_VAL": {
1480   "label": "How much did ... receive in financial assistance income
1481   "during 20.. ?",
1482   "universe": "FIN_YN = 1",
1483   "type": "Continuous",
1484   "role": "Independent",
1485   "topic": "Income",
1486   "subtopic": "Other income",
1487   "values": {
1488     "0": "None or niu",
1489     "1-999999": "Financial assistance"
1490   }
1491 },
1492 "FIN_YN": {
1493   "label": "Did ... receive financial assistance?",
1494   "universe": "All Persons aged 15+",
1495   "type": "Categorical",
1496   "role": "Independent",
1497   "topic": "Income",
1498   "subtopic": "Other income",
1499   "values": {
1500     "0": "Niu",
1501     "1": "Yes",
1502     "2": "No"
1503   }
1504 },
1505 "INT_VAL": {
1506   "label": "Edited total combined interest income",
1507   "universe": "INT_YN = 1",
1508   "type": "Continuous",
1509   "role": "Independent",
1510   "topic": "Income",
1511   "subtopic": "Other income",
1512   "values": {

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1512         "0": "None or niu;",
1513         "1- 999,999": "Dollar amount"
1514     }
1515 },
1516 "INT_YN": {
1517     "label": "Edited total combined interest income, y/n",
1518     "universe": "All Persons aged 15+",
1519     "type": "Categorical",
1520     "role": "Independent",
1521     "topic": "Income",
1522     "subtopic": "Other income"1,
1523     "values": {
1524         "0": "Niu",
1525         "1": "Yes",
1526         "2": "No"
1527     }
1528 },
1529 "OED_TYP1": {
1
1530     "label": "Source 1 other than gi bill received (OED_TYP1- source of
1531             other government assistance)",
1532     "universe": "ED_YN = 1",
1533     "type": "Categorical",
1534     "role": "Independent",
1535     "topic": "Income",
1536     "subtopic": "Other income"1,
1537     "values": {
1538         "0": "Niu",
1539         "1": "Yes",
1540         "2": "No"
1541     }
1542 },
1543 "OED_TYP2": {
1544     "label": "Source 2 other than gi bill received (OED_TYP2-
1545             scholarships, grants etc. from the school)",
1546     "universe": "ED_YN = 1",
1547     "type": "Categorical",

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1546     "role": "Independent",
1547     "topic": "Income",
1548     "subtopic": "Other income", ①
1549     "values": {
1550         "0": "Niu",
1551         "1": "Yes",
1552         "2": "No"
1553     }
1554 },
1555 "OED_TYP3": { ①
1556     "label": "Source other than gi bill received (OED_TYP3- other
assistance (employers friends, etc.)",
1557     "universe": "ED_YN = 1",
1558     "type": "Categorical",
1559     "role": "Independent",
1560     "topic": "Income", ①
1561     "subtopic": "Other income",
1562     "values": {
1563         "0": "Niu",
1564         "1": "Yes",
1565         "2": "No"
1566     }
1567 },
1568 "OI_OFF": {
1569     "label": "Other income sources",
1570     "universe": "OI_YN = 1",
1571     "type": "Categorical",
1572     "role": "Independent",
1573     "topic": "Income",
1574     "subtopic": "Other income",
1575     "values": {
1576         "0": "Niu",
1577         "1": "Social security",
1578         "2": "Private pensions",
1579         "3": "Afdc",
1580         "4": "Other public assistance",

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1581         "5": "Interest",
1582         "6": "Dividends",
1583         "7": "Rents or royalties",
1584         "8": "Estates or trusts",
1585         "9": "State disability payments (worker's comp)",
1586         "10": "Disability payments (own insurance)",
1587         "11": "Unemployment compensation",
1588         "12": "Strike benefits",
1589         "13": "Annuities or paid up insurance policies",
1590         "14": "Not income",
1591         "15": "Longest job",
1592         "16": "Wages or salary",
1593         "17": "Nonfarm self-employment",
1594         "18": "Farm self-employment",
1595         "19": "Anything else",
1596         "20": "Alimony"
1597     },
1598 },
1599 "OI_VAL": {
1600     "label": "How much did ... receive in other incomes",
1601     "universe": "OI_YN = 1",
1602     "type": "Continuous",
1603     "role": "Independent",
1604     "topic": "Income",
1605     "subtopic": "Other income",
1606     "values": {
1607         "0": "None or n/a",
1608         "1-999999": "Other income"
1609     },
1610 },
1611 "OI_YN": {
1612     "label": "Did ... receive cash income not already covered from any
1613             other source?",
1614     "universe": "All Persons aged 15+",
1615     "type": "Categorical",
1616     "role": "Independent",

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1616     "topic": "Income",
1617     "subtopic": "Other income",
1618     "values": {
1619         "0": "None or niu",
1620         "1": "Yes",
1621         "2": "No"
1622     }
1623 },
1624 "PEN_SC1": {
1625     "label": "Retirement income, pension source 1",
1626     "universe": "PEN_YN = 1",
1627     "type": "Categorical",
1628     "role": "Independent",
1629     "topic": "Income",
1630     "subtopic": "Other income",
1631     "values": {
1632         "0": "Niu",
1633         "1": "Company pension",
1634         "2": "Union pension",
1635         "3": "Federal government pension",
1636         "4": "State government pension",
1637         "5": "Local government pension",
1638         "6": "Us military pension",
1639         "7": "Us railroad retirement",
1640         "8": "Other"
1641     }
1642 },
1643 "PEN_SC2": {
1644     "label": "Retirement income, pension source 2",
1645     "universe": "PEN_VAL2 > 0",
1646     "type": "Categorical",
1647     "role": "Independent",
1648     "topic": "Income",
1649     "subtopic": "Other income",
1650     "values": {
1651         "0": "Niu",

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1652     "1": "Company pension",
1653     "2": "Union pension",
1654     "3": "Federal government pension",
1655     "4": "State government pension",
1656     "5": "Local government pension",
1657     "6": "Us military pension",
1658     "7": "Us railroad retirement",
1659     "8": "Other"
1660   },
1661 },
1662 "PEN_VAL1": {
1663   "label": "Retirement income amount, pension source 1",
1664   "universe": "PEN_SC1 > 0",
1665   "type": "Continuous",
1666   "role": "Independent",
1667   "topic": "Income",
1668   "subtopic": "Other income",
1669   "values": {
1670     "0": "None or niu",
1671     "1-999,999": "Pension income"
1672   },
1673 },
1674 "PEN_VAL2": {
1675   "label": "Retirement income amount, pension source 2",
1676   "universe": "PEN_SC2 > 0",
1677   "type": "Continuous",
1678   "role": "Independent",
1679   "topic": "Income",
1680   "subtopic": "Other income",
1681   "values": {
1682     "0": "None or niu",
1683     "1-999,999": "Pension income"
1684   },
1685 },
1686 "PEN_YN": {
1687   "label": "Retirement income, pension y/n",

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1688     "universe": "All Persons aged 15+",
1689     "type": "Categorical",
1690     "role": "Independent",
1691     "topic": "Income",
1692     "subtopic": "Other income",
1
1693     "values": {
1694         "0": "Niu",
1695         "1": "Yes",
1696         "2": "No"
1697     }
1698 },
1699 "PNSN_VAL": {
1
1700     "label": "Total combined amount of pension income received from all
1701             pension sources",
1702     "universe": "PEN_YN = 1",
1703     "type": "Continuous",
1704     "role": "Independent",
1705     "topic": "Income",
1706     "subtopic": "Other income",
1
1707     "values": {
1708         "0": "None or niu",
1709         "1-9,999,999": "Retirement income"
1710     }
1711 },
1712 "PTOTVAL": {
1713     "label": "Total persons income",
1714     "universe": "All Persons aged 15+",
1715     "type": "Continuous",
1716     "role": "Independent",
1717     "topic": "Income",
1718     "subtopic": "Other income",
1719     "values": {
1720         "0": "None",
1721         "negative amt": "Income (loss)",
1722         "positive amt": "Income"
1723     }

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1723     },
1724     "RESNSS1": {
1725       "label": "What were the reasons (you/name) (was/were) getting
1726         Social Security Income last year?",8
1727       "universe": "SS_YN = 1",
1728       "type": "Categorical",
1729       "role": "Independent",
1730       "topic": "Income",
1731       "subtopic": "Other income",
1732       "values": {
1733         "0": "Niu",
1734         "1": "Retired",
1735         "2": "Disabled (adult or child)",
1736         "3": "Widowed",
1737         "4": "Spouse",
1738         "5": "Surviving child",
1739         "6": "Dependent child",
1740         "7": "On behalf of surviving, dependent, or disabled child(ren)
1741           ",
1742         "8": "Other (adult or child)"
1743       }
1744     },
1745     "RESNSS2": {
1746       "label": "What were the reasons (you/name) (was/were) getting
1747         Social Security Income last year?",8
1748       "universe": "SS_YN = 1",
1749       "type": "Categorical",
1750       "role": "Independent",
1751       "topic": "Income",
1752       "subtopic": "Other income",
1753       "values": {
1754         "0": "Niu",
1755         "1": "Retired",

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1756         "5": "Surviving child",
1757         "6": "Dependent child",
1758         "7": "On behalf of surviving, dependent, or disabled child(ren)
1759             ",
1760             "8": "Other (adult or child)"
1761     },
1762     "RESNSSI1": {
1763         "label": "What were the reasons (you/name) (was/were) getting
1764             Supplemental Security Income last year?",  

1765         "universe": "SSI_YN = 1",
1766         "type": "Categorical",
1767         "role": "Independent",
1768         "topic": "Income",
1769         "subtopic": "Other income",
1770         "values": {
1771             "0": "Niu",
1772             "1": "Disabled (adult or child)",
1773             "2": "Blind (adult or child)",
1774             "3": "On behalf of a disabled child",
1775             "4": "On behalf of a blind child",
1776             "5": "Other (adult or child)"
1777         }
1778     },
1779     "RESNSSI2": {
1780         "label": "What were the reasons (you/name) (was/were) getting
1781             Supplemental Security Income last year?",  

1782         "universe": "SSI_YN = 1",
1783         "type": "Categorical",
1784         "role": "Independent",
1785         "topic": "Income",
1786         "subtopic": "Other income",
1787         "values": {
1788             "0": "Niu",
1789             "1": "Disabled (adult or child)",
1790             "2": "Blind (adult or child)",
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1789         "3": "On behalf of a disabled child",
1790         "4": "On behalf of a blind child",
1791         "5": "Other (adult or child)"
1792     },
1793 },
1794 "RETCB_VAL": {
1795     "label": "Retirement contributiion, amount",
1796     "universe": "RETCB_YN = 1",
1797     "type": "Continuous",
1798     "role": "Independent",
1799     "topic": "Income",
1800     "subtopic": "Other income",
1801     "values": {
1802         "0": "None or n/a",
1803         "1-99999": "Amount contributed"
1804     },
1805 },
1806 "RETCB_YN": {
1807     "label": "Retirement contribution, y/n",
1808     "universe": "All people 15 years and over",
1809     "type": "Categorical",
1810     "role": "Independent",
1811     "topic": "Income",
1812     "subtopic": "Other income",
1813     "values": {
1814         "0": "N/A",
1815         "1": "Yes",
1816         "2": "No"
1817     },
1818 },
1819 "RINT_SC1": {
1820     "label": "Interest income, retirement source 1",
1821     "universe": "RINT_YN = 1",
1822     "type": "Categorical",
1823     "role": "Independent",
1824     "topic": "Income",

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1825     "subtopic": "Other income",
1826     "values": {
1827         "0": "Niu",
1828         "1": "401k account",
1829         "2": "403b account",
1830         "3": "Roth ira",
1831         "4": "Regular ira",
1832         "5": "Keogh plan",
1833         "6": "Sep plan (simplified employee pension)",
1834         "7": "Other type of retirement account"
1835     },
1836 },
1837 "RINT_SC2": {
1838     "label": "Interest income, retirement source 2",
1839     "universe": "RINT_YN = 1",
1840     "type": "Categorical",
1841     "role": "Independent",
1842     "topic": "Income",
1843     "subtopic": "Other income",
1844     "values": {
1845         "0": "Niu",
1846         "1": "401k account",
1847         "2": "403b account",
1848         "3": "Roth ira",
1849         "4": "Regular ira",
1850         "5": "Keogh plan",
1851         "6": "Sep plan (simplified employee pension)",
1852         "7": "Other type of retirement account"
1853     },
1854 },
1855 "RINT_VAL1": {
1856     "label": "Interest income amt, retirement source 1",
1857     "universe": "RINT_SC1 > 0",
1858     "type": "Continuous",
1859     "role": "Independent",
1860     "topic": "Income",

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1861     "subtopic": "Other income",
1862     "values": {
1863         "0": "None or niu",
1864         "1-999999": "Ret interest income"
1865     }
1866 },
1867 "RINT_VAL2": {
1868     "label": "Interest income amt, retirement source 2",
1869     "universe": "RINT_SC2 > 0",
1870     "type": "Continuous",
1871     "role": "Independent",
1872     "topic": "Income",
1873     "subtopic": "Other income",
1874     "values": {
1875         "0": "None or niu",
1876         "1-999999": "Ret interest income"
1877     }
1878 },
1879 "RINT_YN": {
1880     "label": "Interest income - retirement, y/n",
1881     "universe": "All Persons aged 15+",
1882     "type": "Categorical",
1883     "role": "Independent",
1884     "topic": "Income",
1885     "subtopic": "Other income",
1886     "values": {
1887         "0": "Niu",
1888         "1": "Yes",
1889         "2": "No"
1890     }
1891 },
1892 "RNT_VAL": {
1893     "label": "How much did ... receive in income from rent after
1894         expenses during 20..?",
1894     "universe": "RNT_YN = 1",
1895     "type": "Continuous",

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1896     "role": "Independent",
1897     "topic": "Income",
1898     "subtopic": "Other income",
1899     "values": {
1900         "0": "None or niu",
1901         "-9999-999999": "Rental income"
1902     },
1903 },
1904 "RNT_YN": {
1905     "label": "Did ... own any land, property, rented to others, or
1906         receive income from royalties, roomers or boarders, or from
1907         estates or trusts?",
1908     "universe": "All Persons aged 15+",
1909     "type": "Categorical",
1910     "role": "Independent",
1911     "topic": "Income",
1912     "subtopic": "Other income",
1913     "values": {
1914         "0": "Niu",
1915         "1": "Yes",
1916         "2": "No"
1917     },
1918     "SRVS_VAL": {
1919         "label": "Total amount of survivor's income received (combined
1920             amounts in edited sources sur_val1 and sur_val2 plus the
1921             unedited sources 3 & 4 starting in 1995)",
1922         "universe": "SUR_YN = 1",
1923         "type": "Continuous",
1924         "role": "Independent",
1925         "topic": "Income",
1926         "subtopic": "Other income",
1927         "values": {
1928             "0": "None or niu",
1929             "1-999999": "Income amount"
1930         }
1931     }
1932 }
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1928     },
1929     "SS_VAL": {
1930         "label": "How much did ... receive in social security payments
1931             during 20.. ?",
1932         "universe": "SS_YN = 1",
1933         "type": "Continuous",
1934         "role": "Independent",
1935         "topic": "Income",
1936         "subtopic": "Other income",
1937         "values": {
1938             "0": "None or niu",
1939             "1-99999": "Social security"
1940         },
1941     },
1942     "SS_YN": {
1943         "label": "Who received social security payments either for
1944             themselves or as combined payments with other family members?",
1945         "universe": "All Persons aged 15+",
1946         "type": "Categorical",
1947         "role": "Independent",
1948         "topic": "Income",
1949         "subtopic": "Other income",
1950         "values": {
1951             "0": "Niu",
1952             "1": "Yes",
1953             "2": "No"
1954         },
1955     },
1956     "SSI_VAL": {
1957         "label": "How much did ... receive in supplemental security income
1958             during 20..?",
1959         "universe": "SSI_YN = 1",
1960         "type": "Continuous",

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1961     1
1962         "values": {
1963             "0": "None or niu",
1964             "1-99999": "Supplemental security income"
1965         },
1966     2
1967         "SSI_YN": {
1968             "label": "Did ... received ssi?",
1969             "universe": "All Persons aged 15+",
1970             "type": "Categorical",
1971             "role": "Independent",
1972             "topic": "Income",
1973             "subtopic": "Other income",
1974             "values": {
1975                 "0": "Niu",
1976                 "1": "Yes",
1977                 "2": "No"
1978             }
1979         },
1980         "STRKUC": {
1981             "label": "At any time during 20.. did ... receive any union
1982             unemployment or strike benefits?",
1983             "universe": "UC_YN = 1",
1984             "type": "Categorical",
1985             "role": "Independent",
1986             "topic": "Income",
1987             "subtopic": "Other income",
1988             "values": {
1989                 "0": "Niu",
1990                 "1": "Yes",
1991                 "2": "No"
1992             }
1993         },
1994         "SUBUC": {
1995             "label": "At any time during 20.. did ... receive any supplemental
1996             unemployment benefits?",
1997             "universe": "UC_YN = 1",
1998         }

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1995      "type": "Categorical",
1996      "role": "Independent",
1997      "topic": "Income",
1998      "subtopic": "Other income",  
1
1999      "values": {
2000          "0": "Niu",
2001          "1": "Yes",
2002          "2": "No"
2003      }
2004  },
2005  "SUR_SC1": {
2006      "label": "What was the source of this other widow or survivor  
income?",  
1
2007      "universe": "SUR_YN = 1",
2008      "type": "Categorical",
2009      "role": "Independent",
2010      "topic": "Income",
2011      "subtopic": "Other income",  
1
2012      "values": {
2013          "0": "None or niu",
2014          "1": "Company or union survivor pension",
2015          "2": "Federal government",
2016          "3": "Us military retirement survivor pension",
2017          "4": "State or local gov't survivor pension",
2018          "5": "Us railroad retirement survivor pension",
2019          "6": "Worker compensation survivor",
2020          "7": "Black lung",
2021          "8": "Regular payments from estates or trusts",
2022          "9": "Regular payments from annuities or paid-up life insurance
2023          ",
2024          "10": "Other or don't know"
2025      }
2026  "SUR_SC2": {
2027      "label": "What was the source of this other widow or survivor  
income?",  
1

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2028     "universe": "SUR_YN = 1",
2029     "type": "Categorical",
2030     "role": "Independent",
2031     "topic": "Income",          8
2032     "subtopic": "Other income",
2033     "values": {
2034         "0": "None or niu",
2035         "1": "Company or union survivor pension",
2036         "2": "Federal government",
2037         "3": "Us military retirement survivor pension",
2038         "4": "State or local gov't survivor pension",
2039         "5": "Us railroad retirement survivor pension",
2040         "6": "Worker compensation survivor",
2041         "7": "Black lung",
2042         "8": "Regular payments from estates or trusts",
2043         "9": "Regular payments from annuities or paid-up life insurance"
2044         "",
2045     },
2046 },
2047 "SUR_VAL1": {
2048     "label": "How much did ... receive (survivor source type) during
2049     "20.. ?",
2050     "universe": "SUR_YN = 1",
2051     "type": "Continuous",
2052     "role": "Independent",
2053     "topic": "Income",
2054     "subtopic": "Other income",
2055     "values": {
2056         "0": "None or niu",
2057         "1-999,999": "Survivor's income"
2058     },
2059 },
2060     "label": "How much did ... receive (source type) during 20.. ?",
2061     "universe": "SUR_YN = 1",

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2062     "type": "Continuous",
2063     "role": "Independent",
2064     "topic": "Income",
2065     "subtopic": "Other income",
2066     "values": {
2067       "0": "None or niu",
2068       "1-999,999": "Survivor's income"
2069     },
2070   },
2071   "SUR_YN": {
2072     "label": "During 20.. did ... receive any survivor benefits such as
2073       widow's pensions, estates, trusts, insurance annuities, or
2074       other survivor's income?",
2075     "universe": "All Persons aged 15+",
2076     "type": "Categorical",
2077     "role": "Independent",
2078     "topic": "Income",
2079     "subtopic": "Other income",
2080     "values": {
2081       "0": "Niu",
2082       "1": "Yes",
2083       "2": "No"
2084     },
2085   },
2086   "TRDINT_VAL": {
2087     "label": "Interest amount, exlcuding retirment account interest",
2088     "universe": "INT_YN = 1",
2089     "type": "Continuous",
2090     "role": "Independent",
2091     "topic": "Income",
2092     "subtopic": "Other income",
2093     "values": {
2094       "all": "Dollar value"
2095     },
2096   },
2097   "UC_VAL": {

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2096     "label": "How much did ... receive in unemployment benefits during
2097         20..?",  

2098     "universe": "UC_YN = 1",
2099     "type": "Continuous",
2100     "role": "Independent",
2101     "topic": "Income",
2102     "subtopic": "Other income",
2103     "values": {
2104         "0": "None or n/a",
2105         "1-99999": "Unemployment compensation"
2106     },
2107     "UC_YN": {
2108         "label": "Any type of unemployment compensation? (Combination of
2109             subuc, strkuc, and uctot_yn)",
2110         "universe": "UC_YN = 1",
2111         "type": "Categorical",
2112         "role": "Independent",
2113         "topic": "Income",
2114         "subtopic": "Other income",
2115         "values": {
2116             "0": "N/A",
2117             "1": "Yes",
2118             "2": "No"
2119         },
2120     "VET_TYP1": {
2121         "label": "What type of veterans payments did .... receive? (
2122             VET_TYP1- disability compensation?)",
2123         "universe": "VET_YN = 1",
2124         "type": "Categorical",
2125         "role": "Independent",
2126         "topic": "Income",
2127         "subtopic": "Other income",
2128         "values": {
2129             "0": "N/A",
2130             "1": "Yes",
2131             "2": "No"
2132         }
2133     }
2134 }
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2129         "1": "Yes",
2130         "2": "No"
2131     },
2132 },
2133 "VET_TYP2": {
2134     "label": "What type of veterans payments did .... receive? (
2135         VET_TYP2- survivor benefits?)",
2136     "universe": "VET_YN = 1",
2137     "type": "Categorical",
2138     "role": "Independent",
2139     "topic": "Income",
2140     "subtopic": "Other income",
2141     "values": {
2142         "0": "Niu",
2143         "1": "Yes",
2144         "2": "No"
2145     },
2146 },
2147 "VET_TYP3": {
2148     "label": "What type of veterans payments did .... receive? (
2149         VET_TYP3- veteran's pension?)",
2150     "universe": "VET_YN = 1",
2151     "type": "Categorical",
2152     "role": "Independent",
2153     "topic": "Income",
2154     "subtopic": "Other income",
2155     "values": {
2156         "0": "Niu",
2157         "1": "Yes",
2158         "2": "No"
2159     },
2160     "VET_TYP4": {
2161         "label": "What type of veterans payments did .... receive? (
2162             VET_TYP4- education assistance?)",
2163         "universe": "VET_YN = 1",

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2162     "type": "Categorical",
2163     "role": "Independent",
2164     "topic": "Income",
2165     "subtopic": "Other income",
2166     "values": {
2167       "0": "Niu",
2168       "1": "Yes",
2169       "2": "No"
2170     },
2171   },
2172   "VET_TYP5": {
2173     "label": "What type of veterans payments did .... receive? ("
2174     "VET_TYP5- other veteran's payments?)",
2175     "universe": "VET_YN = 1",
2176     "type": "Categorical",
2177     "role": "Independent",
2178     "topic": "Income",
2179     "subtopic": "Other income",
2180     "values": {
2181       "0": "Niu",
2182       "1": "Yes",
2183       "2": "No"
2184     },
2185   "VET_VAL": {
2186     "label": "How much did ... receive from veterans' administration"
2187     "during 20..?", "universe": "VET_YN = 1",
2188     "type": "Continuous",
2189     "role": "Independent",
2190     "topic": "Income",
2191     "subtopic": "Other income",
2192     "values": {
2193       "0": "None or niu",
2194       "1-9999999": "Veterans' payments"
2195     }

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2196     },
2197     "VET_YN": {
2198         "label": "Did ... receive veterans' payments?",
2199         "universe": "All Persons aged 15+",
2200         "type": "Categorical",
2201         "role": "Independent",
2202         "topic": "Income", 1
2203         "subtopic": "Other income",
2204         "values": {
2205             "0": "Niu",
2206             "1": "Yes",
2207             "2": "No"
2208         }
2209     },
2210     "WC_TYPE": {
6
2211         "label": "What was source of these payments?",
2212         "universe": "WC_YN = 1",
2213         "type": "Categorical",
2214         "role": "Independent",
2215         "topic": "Income",
2216         "subtopic": "Other income",
8
2217         "values": {
2218             "0": "Not in universe",
2219             "1": "State worker's compensation",
2220             "2": "Employer or employers insurance",
2221             "3": "Own insurance",
2222             "4": "Other"
2223         }
2224     },
2225     "WC_VAL": {
2226         "label": "How much compensation did ... receive during 20..?",
2227         "universe": "WC_YN = 1",
2228         "type": "Continuous",
2229         "role": "Independent",
2230         "topic": "Income",
2231         "subtopic": "Other income",

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2232     "values": {  

2233         "0": "None or niu",  

2234         "1-99999": "Worker's compensation"  

2235     },  

2236 },  

2237 "WC_YN": {  

2238     "label": "During 20.. did ... receive any worker's compensation  

payments or other payments as a result of a job related injury  

or illness?",  

2239     "universe": "All Persons aged 15+",  

2240     "type": "Categorical",  

2241     "role": "Independent",  

2242     "topic": "Income",  

2243     "subtopic": "Other income",  

2244     "values": {  

2245         "0": "Niu",  

2246         "1": "Yes",  

2247         "2": "No"  

2248     },  

2249 },  

2250 "PAW_TYP": {  

2251     "label": "What type of program did... receive CASH assistance?",  

2252     "universe": "PAW_YN = 1",  

2253     "type": "Categorical",  

2254     "role": "Independent",  

2255     "topic": "Income",  

2256     "subtopic": "Non-cash benefits",  

2257     "values": {  

2258         "0": "Niu",  

2259         "1": "TANF/AFDC",  

2260         "2": "Other",  

2261         "3": "Both"  

2262     },  

2263 },  

2264 "PAW_VAL": {

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2265     "label": "How much did ... receive in public assistance or welfare
2266         during 20..?",  

2267     "universe": "PAW_YN = 1",
2268     "type": "Continuous",
2269     "role": "Independent",
2270     "topic": "Income",
2271     "subtopic": "Non-cash benefits",
2272     "values": {
2273         "0": "None or niu",
2274         "1-99999": "Public assistance"
2275     },
2276     "PAW_YN": {
2277         "label": "At any time during 20.., even for one month, did...
2278             receive an CASH assistance from a state or county welfare
2279             program such as (State program name fill)?",
2280         "universe": "All Persons aged 15+",
2281         "type": "Categorical",
2282         "role": "Independent",
2283         "topic": "Income",
2284         "subtopic": "Non-cash benefits",
2285         "values": {
2286             "0": "Niu",
2287             "1": "Yes",
2288             "2": "No"
2289         },
2290         "PENINCL": {
2291             "label": "Was ... included in that plan?",
2292             "universe": "PENPLAN = 1",
2293             "type": "Categorical",
2294             "role": "Independent",
2295             "topic": "Income",
2296             "subtopic": "Non-cash benefits",
2297             "values": {
2298                 "0": "Niu",

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2298         "1": "Yes",
2299         "2": "No"
2300     },
2301 },
2302 "PENPLAN": {
2303     "label": "Other than social security did the employer or union that
2304         ... worked for in 20... have a pension or other type of
2305             retirement plan?",
2306     "universe": "WRK_CK = 1",
2307     "type": "Categorical",
2308     "role": "Independent",
2309     "topic": "Income",
2310     "subtopic": "Non-cash benefits",
2311     "values": {
2312         "0": "Niu",
2313         "1": "Yes",
2314         "2": "No"
2315     },
2316     "WICYN": {
2317         "label": "Who received WIC?",
2318         "universe": "Adult female",
2319         "type": "Categorical",
2320         "role": "Independent",
2321         "topic": "Income",
2322         "subtopic": "Non-cash benefits",
2323         "values": {
2324             "0": "Niu",
2325             "1": "Received WIC",
2326             "2": "Did not receive WIC"
2327         },
2328     },
2329     "CHCARE_YN": {
2330         "label": "Paid child care was needed for this child?",
2331         "universe": "Persons age 15+ with children",
2332         "type": "Categorical",

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2332     "role": "Independent",
2333     "topic": "Income",
2334     "subtopic": "Supplemental poverty measure",
2335     "values": {
2336         "0": "Niu",
2337         "1": "Yes",
2338         "2": "No"
2339     }
2340 },
2341 "CHELSEW_YN": {
2342     "label": "Does this person have a child living outside the
2343             household?",
2344     "universe": "All persons aged 15+",
2345     "type": "Categorical",
2346     "role": "Independent",
2347     "topic": "Income",
2348     "subtopic": "Supplemental poverty measure",
2349     "values": {
2350         "0": "Niu",
2351         "1": "Yes",
2352         "2": "No"
2353     }
2354 },
2355 "CHELSEW_YN": {
2356     "label": "Does this person have a child living outside the
2357             household?",
2358     "universe": "All persons aged 15+",
2359     "type": "Categorical",
2360     "role": "Independent",
2361     "topic": "Income",
2362     "subtopic": "Supplemental poverty measure",
2363     "values": {
2364         "0": "Niu",
2365         "1": "Yes",
2366         "2": "No"
2367 }
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2366     },
2367     "CHSP_VAL": {
2368         "label": "What is the annual amount of child support paid?",
2369         "universe": "CHSP_YN = 1",
2370         "type": "Continuous",
2371         "role": "Independent",
2372         "topic": "Income",
2373         "subtopic": "Supplemental poverty measure",
2374         "values": {
2375             "0": "Niu",
2376             "1-99999": "Amount paid in child support"
2377         }
2378     },
2379     "CHSP_YN": {
2380         "label": "Is this person required to pay child support?",
2381         "universe": "CHELSEW_YN",
2382         "type": "Categorical",
2383         "role": "Independent",
2384         "topic": "Income",
2385         "subtopic": "Supplemental poverty measure",
2386         "values": {
2387             "0": "Niu",
2388             "1": "Yes",
2389             "2": "No"
2390         }
2391     },
2392     "CSP_VAL": {
2393         "label": "How much did ... receive in child support payments?",
2394         "universe": "CHSP_YN = 1",
2395         "type": "Continuous",
2396         "role": "Independent",
2397         "topic": "Income",
2398         "subtopic": "Supplemental poverty measure",
2399         "values": {
2400             "0": "None or niu",
2401             "1-99999": "Child support"

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2402         }
2403     },
2404     "CSP_YN": {
2405         "label": "Did ... receive child support payments?",
2406         "universe": "All Persons aged 15+",
2407         "type": "Categorical",
2408         "role": "Independent",
2409         "topic": "Income",
2410         "subtopic": "Supplemental poverty measure",
2411         "values": {
2412             "0": "Niu",
2413             "1": "Yes",
2414             "2": "No"
2415         }
2416     },
2417     "ACTC_CRD": {
2418         "label": "Additional child tax credit",
2419         "universe": "Tax unit head or dependent filer",
2420         "type": "Continuous",
2421         "role": "Independent",
2422         "topic": "Income",
2423         "subtopic": "Tax model items",
2424         "values": {
2425             "0": "None",
2426             "1-99999": "Dollar amount"
2427         }
2428     },
2429     "AGI": {
2430         "label": "Adjusted gross income",
2431         "universe": "Tax unit head or dependent filer",
2432         "type": "Continuous",
2433         "role": "Independent",
2434         "topic": "Income",
2435         "subtopic": "Tax model items",
2436         "values": {
2437             "0": "None",
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2438         "-9999-999999": "Dollar amount"
2439     }
2440 },
2441 "CTC_CRD": {
2442     "label": "Child tax credit",
2443     "universe": "Tax unit head or dependent filer",
2444     "type": "Continuous",
2445     "role": "Independent",
2446     "topic": "Income",
2447     "subtopic": "Tax model items",
2448     "values": {
2449         "0": "None",
2450         "1-99999": "Dollar amount"
2451     }
2452 },
2453 "EIT_CRED": {
2454     "label": "Earn income tax credit",
2455     "universe": "Tax unit head or dependent filer",
2456     "type": "Continuous",
2457     "role": "Independent",
2458     "topic": "Income",
2459     "subtopic": "Tax model items",
2460     "values": {
2461         "0": "None",
2462         "1-9999": "Dollar amount"
2463     }
2464 },
2465 "FED_RET": {
2466     "label": "Federal retirement payroll deduction",
2467     "universe": "Tax unit head or dependent filer",
2468     "type": "Continuous",
2469     "role": "Independent",
2470     "topic": "Income",
2471     "subtopic": "Tax model items",
2472     "values": {
2473         "0": "None",
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2474         "1-999999": "Dollar amount"
2475     }
2476 },
2477 "FEDTAX_AC": {
2478     "label": "Federal income tax liability, after all credits",
2479     "universe": "Tax unit head or dependent filer",
2480     "type": "Continuous",
2481     "role": "Independent",
2482     "topic": "Income",
2483     "subtopic": "Tax model items",
2484     "values": {
2485         "0": "None",
2486         "-9999-999999": "Dollar amount"
2487     }
2488 },
2489 "FEDTAX_BC": {
2490     "label": "Federal income tax liability, before credits",
2491     "universe": "Tax unit head or dependent filer",
2492     "type": "Continuous",
2493     "role": "Independent",
2494     "topic": "Income",
2495     "subtopic": "Tax model items",
2496     "values": {
2497         "0": "None",
2498         "-9999-999999": "Dollar amount"
2499     }
2500 },
2501 "FICA": {
2502     "label": "Social security retirement payroll deduction",
2503     "universe": "All persons",
2504     "type": "Continuous",
2505     "role": "Independent",
2506     "topic": "Income",
2507     "subtopic": "Tax model items",
2508     "values": {
2509         "0": "None",
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2510           "1-99999": "Dollar amount"
2511       },
2512   },
2513   "FILESTAT": {
2514     "label": "Tax filer status",
2515     "universe": "All persons",
2516     "type": "Categorical",
2517     "role": "Independent",
2518     "topic": "Income",
2519     "subtopic": "Tax model items",
2520     "values": {
2521       "1": "Joint, both<65",
2522       "2": "Joint, one ><65 & one 65+",
2523       "3": "Joint, both 65+",
2524       "4": "Head of household",
2525       "5": "Single",
2526       "6": "Non-filer"
2527     },
2528   },
2529   "MARG_TAX": {
2530     "label": "Marginal tax rate",
2531     "universe": "Tax unit head or dependent filer",
2532     "type": "Continuous",
2533     "role": "Independent",
2534     "topic": "Income",
2535     "subtopic": "Tax model items",
2536     "values": {
2537       "0": "None",
2538       "1-99": "Marginal rate"
2539     }
2540   },
2541   "PRSWKXPNS": {
2542     "label": "Work expenses",
2543     "universe": "A AGE > 17 or HHDFMX = 1,2,46, or 47",
2544     "type": "Continuous",
2545     "role": "Independent",

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2546     "topic": "Income",
2547     "subtopic": "Tax model items",
2548     "values": {
2549       "0": "None",
2550       "1-1999": "Dollar amount"
2551     }
2552   },
2553   "STATETAX_A": {
2554     "label": "State income tax liability, after all credits",
2555     "universe": "Tax unit head or dependent filer",
2556     "type": "Continuous",
2557     "role": "Independent",
2558     "topic": "Income",
2559     "subtopic": "Tax model items",
2560     "values": {
2561       "0": "None",
2562       "-9999-999999": "Dollar amount"
2563     }
2564   },
2565   "STATETAX_B": {
2566     "label": "State income tax liability, before credits",
2567     "universe": "Tax unit head or dependent filer",
2568     "type": "Continuous",
2569     "role": "Independent",
2570     "topic": "Income",
2571     "subtopic": "Tax model items",
2572     "values": {
2573       "0": "None",
2574       "-9999-999999": "Dollar amount"
2575     }
2576   },
2577   "TAX_INC": {
2578     "label": "Taxable income amount",
2579     "universe": "Tax unit head or dependent filer",
2580     "type": "Continuous",
2581     "role": "Independent",
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2582     "topic": "Income",
2583     "subtopic": "Tax model items",
2584     "values": {
2585         "0": "None",
2586         "-9999-999999": "Dollar amount"
2587     }
2588 },
2589 "PERLIS": {
2590     "label": "Poverty level of persons (Subfamily members have primary
2591         family recode)",
2592     "universe": "All persons",
2593     "type": "Categorical",
2594     "role": "Independent",
2595     "topic": "Poverty",
2596     "subtopic": "Poverty",
2597     "values": {
2598         "-1": "Not in poverty universe",
2599         "1": "Below poverty level",
2600         "2": "100 - 124 percent of the poverty level",
2601         "3": "125 - 149 percent of the poverty level",
2602         "4": "150 and above the poverty level"
2603     }
2604 },
2605 "POV_UNIV": {
2606     "label": "Poverty universe flag",
2607     "universe": "All persons",
2608     "type": "Categorical",
2609     "role": "Independent",
2610     "topic": "Poverty",
2611     "subtopic": "Poverty",
2612     "values": {
2613         "0": "Not in poverty universe",
2614         "1": "In poverty universe"
2615     }
2616 },

```

```
2617     "label": "Health status",
2618     "universe": "All persons",
2619     "type": "Categorical",
2620     "role": "Independent",
2621     "topic": "Health insurance",
2622     "subtopic": "Health status",
2623     "values": {
2624       "1": "Excellent",
2625       "2": "Very good",
2626       "3": "Good",
2627       "4": "Fair",
2628       "5": "Poor"
2629     }
2630   },
2631   "SPM_ACTC": {
2632     "label": "SPM units Additional Child Tax Credit",
2633     "universe": "All persons",
2634     "type": "Continuous",
2635     "role": "Independent",
2636     "topic": "Supplemental poverty measure",
2637     "subtopic": "SPM unit characteristics",
2638     "values": {
2639       "0-99999": "Dollar amount"
2640     }
2641   }
2642 }
```

### 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)

```

1 import os
2 import time
3 import json
4
5 # Directory
6 def create_dir(dir):
7     try:
8         os.makedirs(dir)
9     except FileExistsError:
10        pass
11
12 # Backup
13 def backup_duplicate(file_dir, filename, format, backup_dir, info):
14     filepath = f"{file_dir}/{filename}.{format}"
15     date = time.strftime("%Y%m%d", time.localtime(time.time()))
16     if os.path.isfile(filepath):
17         backup_subdir = f"{backup_dir}/{date}/{file_dir.replace('../', '')}"
18         create_dir(backup_subdir)
19         filepath_backup = f"{backup_subdir}/{filename}-backup.{format}"
20         os.replace(filepath, filepath_backup)
21         if info:
22             print(f"{filepath} previously exists")

```

```

23         print(f"Back up to {filepath_backup}")
24     elif info:
25         print(f"{filepath} does not previously exists")
26
27 # Import/export dict/JSON
28 def import_dict(metadatapath):
29     with open(metadatapath) as myfile:
30         indep_contents = myfile.read()
31     return json.loads(indep_contents)
32
33 def export_json(dictfile, jsonfile):
61    with open(jsonfile, 'w', encoding='utf-8') as f:
34        json.dump(dictfile, f, ensure_ascii=False, indent=4)
35
36
37 def export_txt(string, txtfile):
38     f = open(txtfile, 'w')
39     f.write(string)
40     f.close()

```

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

```

1 import pandas as pd
2
3 def extract_dict_cat(indep_dict):
4     return {attr: info for (attr, info) in indep_dict.items() if indep_dict
5            [attr]['type'] == 'Categorical'}
6
7 def extract_dict_cont(indep_dict):
8     return {attr: info for (attr, info) in indep_dict.items() if indep_dict
9            [attr]['type'] == 'Continuous'}
10
11 def sort_cols(df_indep, indep_dict):
12     sorted_cols = sorted(
13         df_indep.head(),
14         key=lambda attr: indep_dict[attr]['type'],

```

```

13     reverse=True
14 )
15 return df_indep[sorted_cols]
16
17 def indep_info(df_indep, indep_dict):
18     df_info = pd.DataFrame({'variable': df_indep.head().columns})
19     df_info['type'] = df_info['variable'].apply(lambda attr: indep_dict[
20         attr]['type'])
21     minmax = df_indep.agg(['min','max']).values.tolist()
22     df_info['min'] = minmax[0]
23     df_info['max'] = minmax[1]
24     del minmax
25
26     return df_info
27
28 def count_info(df_info):
29     df_count = df_info.groupby('type').count().reset_index()[['type','
30         variable']]
31     df_count.rename(columns = {'variable': 'count'}, inplace=True)
32     df_count.sort_values('type', ascending=False, inplace=True,
33         ignore_index=True)
34
35     return df_count

```

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

```

1 import os
2 import urllib.request
3 import pandas as pd
4 import pyarrow
5
6 from module.utility import create_dir, backup_duplicate
7
8 # Import
9 def import_dataset(dataset_name, feather_dir, sas_dir='', sas_url=''):
10     filepath_feather = f"{feather_dir}/{dataset_name}.feather"
11

```

```

12     if os.path.isfile(filepath_feather):
13         print(f"{filepath_feather} is found")
14         print(f"{filepath_feather} was previously preprocessed")
15         df0 = pd.read_feather(filepath_feather)
16     else:
17         print(f"{filepath_feather} is not found")
18         if sas_dir == '':
19             raise Exception("SAS data directory is empty")
20         filepath_sas = f"sas_dir/{dataset_name}.sas7bdat"
21         if os.path.isfile(filepath_sas):
22             print(f"{filepath_sas} is found")
23         else:
24             print(f"{filepath_sas} is not found")
25             create_dir('original/data-orig')
26             print(f"{filepath_sas} will be downloaded")
27             print("Download starts")
28             try:
29                 urllib.request.urlretrieve(sas_url, filepath_sas)
30                 print("Download finishes")
31             except:
32                 raise Exception("Download fails")
33                 print(f"{filepath_sas} is successfully downloaded")
34             df0 = pd.read_sas(filepath_sas)
35
36             print(f"\nNumber of original data: {len(df0)}")
37             df0 = df0[df0['COV']!=0]
38             print(f"An infant born after calendar year (COV = 0) is excluded")
39             print(f"Number of training data: {len(df0)}")
40             return df0
41
42 # Export
43 def export_dataset(df, file_dir, dataset_name, format, info=True,
44                     backup_dir=''):
45     create_dir(file_dir)
46     if format == 'feather' or format == 'csv':
47         filepath = f"{file_dir}/{dataset_name}.{format}"

```

```

47     if backup_dir != '':
48         backup_duplicate(
49             file_dir=file_dir, filename=dataset_name,
50             format=format,
51             backup_dir=backup_dir, info=info
52         )
53     if format == 'feather':
54         df.to_feather(filepath)
55     else:
56         df.to_csv(filepath, index=False)
57     if info:
58         print(f"The dataframe is successfully exported to {filepath}")
59     else:
60         print(f"Input format {format} is unrecognized")

```

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

```

1 import sys
2 import time
3 import pandas as pd
4 import matplotlib.pyplot as plt
5
6 from module.utility import create_dir, backup_duplicate
7 from module.dataset import export_dataset
8
9 # Variables
10 def describe_var(var_dict, role='independent'):
11     num_cat = 0
12     num_cont = 0
13     for key in var_dict:
14         if var_dict[key]['type'] == 'Categorical':
15             num_cat += 1
16         else:
17             num_cont += 1

```

```
18     print(f"There are {num_cat + num_cont} {role} variables of interest:  
19         num_cat} categorical and {num_cont} continuous")  
20  
21 # Cross Tabulation Analysis  
22 def crosstab(df, indep_dict, cont_bins, plot, output_dir, log_filepath,  
23     backup_dir=''):  
24     dir_main = f"{output_dir}/tab-cbins-{cont_bins}"  
25  
26     116  
27     for key, val in indep_dict.items():  
28         fname_main = f"{key}-cbins-{cont_bins}"  
29  
30         if val['type'] == "Categorical":  
31             crossstab = pd.crosstab(index=df[key].map(lambda x: val['values'][str(x)]), columns=df['code'])  
32  
33         else:  
34             dat = df[[key, 'code']].copy()  
35             dat['bins'] = pd.cut(dat[key], bins=cont_bins)  
36             crossstab = pd.crosstab(index=dat['bins'], columns=dat['code'])  
37             del dat  
38  
39             print(key)  
40             print(f"Label: {val['label']}")  
41             print(f"Universe: {val['universe']}")  
42             print(f>Type: {val['type']}")  
43             print(f"Topic: {val['topic']}")  
44             print(f"Subtopic: {val['subtopic']}")  
45             print("\n")  
46  
47             print(f"Code: Employment-based plan (GRP) | Direct-purchase plan (DIR) | Public health insurance (PUB)")  
48             print(crossstab)  
49             ...  
50  
51             dir_crosstab = f"{dir_main}/cross-{cont_bins}"  
52             create_dir(dir_crosstab)  
53             export_dataset(  
54                 crossstab,
```

```
50     file_dir=f"{dir_crosstab}/feather", dataset_name=f"{fname_main}-
51         cross",
52         format='feather', info=False,
53         backup_dir=backup_dir
54     )
55     export_dataset(
56         crosstab,
57         file_dir=f"{dir_crosstab}/csv", dataset_name=f"{fname_main}-
58             cross",
59             format='csv', info=False,
60             backup_dir=backup_dir
61     )
62     """
63     print("\n")
64
65     if plot:
66         barplot = crosstab.plot.bar()
67         barplot.legend(title='(GRP,DIR,PUB)',
68                         bbox_to_anchor=(1,1.02),
69                         loc='upper left')
70         plt.title(val['label'])
71         plt.xlabel(key)
72         plt.ylabel('Frequency')
73         ls_format = ['svg', 'pgf', 'pdf']
74         for format in ls_format:
75             dir_fig = f"{dir_main}/figures/{format}"
76             fname = f"{key}-cbins-{cont_bins}"
77             figpath = f'{dir_fig}/{fname}.{format}'
78             create_dir(dir_fig)
79             backup_duplicate(
80                 file_dir=dir_fig, filename=fname,
81                 format=format,
82                 backup_dir=backup_dir, info=False
83             )
84             f = open(log_filepath, 'a')
85             temp = sys.stdout
```

```
84         sys.stdout = f
85         count, tries = 0, 4
86         success = False
87         while count < tries:
88             try:
89                 plt.savefig(figpath, bbox_inches='tight')
90                 success = True
91                 break
92             except:
93                 pass
94             count += 1
95             if not success:
96                 80
97                 curtime = time.strftime("%Y-%m-%d %H:%M:%S", time.
98                 localtime(time.time()))
99                 print(f"{curtime} | {key}: {figpath} cannot be saved")
100                sys.stdout = temp
101                f.close()
102                #plt.show()
103
104                dftb = crosstb.reset_index().rename_axis(None, axis=1)
105                dftb[dftb.columns[1:]] = dftb[dftb.columns[1:]].astype('uint32')
106                export_dataset(
107                    dftb,
108                    file_dir=f"{dir_main}/feather", dataset_name= fname_main,
109                    format='feather', info=False,
110                    backup_dir=backup_dir
111                )
112                export_dataset(
113                    dftb,
114                    file_dir=f"{dir_main}/csv", dataset_name= fname_main,
115                    format='csv', info=False,
116                    backup_dir=backup_dir
117                )
118                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)

```

1 import re
25
2 import pandas as pd
3
4 @pd.api.extensions.register_dataframe_accessor("thesis")
5 class ThesisExtension:
6     def __init__(self, pandas_obj):
7         #self._validate(pandas_obj, list(indep_dict.keys()) + ['COV'] +
8         #               depAttrs)
8         self.dataset = pandas_obj
9
10    ...
11
11    @staticmethod
12    def _validate(obj, cols):
13        if any(x not in obj.columns for x in cols):
14            raise AttributeError("Some attributes are missing")

```

```
15      ...
16
17  def select(self, cols):
18      85
19      self.dataset.drop(self.dataset.columns.difference(cols), axis=1,
20                         inplace=True)
21
22  def show_type(self, option='short'):
23      if option.lower() == 'full':
24          75
25          with pd.option_context('display.max_rows', None, 'display.
26                                max_columns', None):
27              print(self.dataset.dtypes)
28
29      else:
30          print(self.dataset.dtypes)
31
32
33  @staticmethod
34  def retype(ser):
35      if all(ser.apply(lambda x: isinstance(x, int))):
36          flag_int = True
37      elif all(ser.apply(lambda x: x.is_integer())):
38          flag_int = True
39      else:
40          flag_int = False
41
42      if flag_int:
43          if all(ser.apply(lambda x: x>=0)):
44              if max(ser) <= 255:
45                  return ser.astype('uint8')
46              elif max(ser) <= 65535:
47                  return ser.astype('uint16')
48              else:
49                  return ser.astype('uint32')
50          else:
51              if min(ser) >= -128 and max(ser) <= 127:
52                  return ser.astype('int8')
53              elif min(ser) >= -32768 and max(ser) <= 32767:
54                  return ser.astype('int16')
```

```

49             else:
50                 return ser.astype('int32')
51             else:
52                 return ser.astype('float32')
53
54     def code(self, indep_dict, dep_attrs):
55         self.select(list(indep_dict.keys()) + ['COV'] + dep_attrs)
56         for v in indep_dict.keys():
57             if indep_dict[v]['type'] == 'Categorical':
58                 self.dataset[v] = self.dataset[v].astype('int8').astype(
59                     'category')
60             else:
61                 self.dataset[v] = self.retype(self.dataset[v])
62         self.dataset['COV'] = self.dataset['COV'].astype('int8').astype(
63             'category')
64         self.dataset[dep_attrs] = self.dataset[dep_attrs].astype('int8')
65         self.dataset['class_orig'] = 0
66         self.dataset['code_orig'] = ""
67         for v in dep_attrs:
68             self.dataset[v] = self.dataset[v].replace([2.0, 1.0], [False,
69                 True])
70             self.dataset['class_orig'] = 2*self.dataset['class_orig'] +
71                 self.dataset[v]
72             self.dataset['code_orig'] = self.dataset['code_orig'] + self.
73                 dataset[v].replace([True, False], ['Y', 'N'])
74         self.dataset[dep_attrs] = self.dataset[dep_attrs].astype('category'
75             )
76         self.dataset['class_orig'] = self.dataset['class_orig'].astype(
77             'int8').astype('category')
78         self.dataset['code_orig'] = self.dataset['code_orig'].astype(
79             'category')
80
81     def recode(self):
82         self.dataset['code'] = self.dataset['code_orig'].apply(
83             lambda v: 'NY_' if re.match('(NY)', v)

```

```

76         else 'Y1Y' if re.match(r'^Y(?:\w*Y)', v) # Raw string to
77             prevent invalid escape sequence '\w'
78     else v
79     ).astype('category')
80     self.dataset['class'] = self.dataset[['class_orig', 'code']].apply(
81         lambda v: 2 if v['code'] == 'NY_'
82         else 3 if v['code'] == 'YNN'
83         else 4 if v['code'] == 'Y1Y'
84         else v['class_orig'],
85         axis=1
86     ).astype('int8').astype('category')

```

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

```

1 import re
2
3 import pandas as pd
4
5 @pd.api.extensions.register_dataframe_accessor("data")
6 class Data:
7     def __init__(self, pandas_obj, indep_dict):
8         self.dataset = pandas_obj
9         self.metadata = indep_dict
10
11     def encodecat(self):
12         cat_change = ""
13         for attr in self.metadata.keys():
14             if self.metadata[attr]['type'] == 'Categorical':
15                 le = LabelEncoder()
16                 le.fit(self.dataset[attr])
17                 self.dataset[attr] = list(le.transform(self.dataset[attr])._
18                     astype('int8'))
19                 newkeys = list()
20                 unseen = 0
21                 for strval in self.metadata[attr]['values'].keys():
22

```

```

21         try:
22             newkeys.append(int(le.transform([int(strval)])))
23         except ValueError: # for previously unseen labels
24             unseen -= 1
25             newkeys.append(unseen)
26         if list(self.metadata[attr]['values'].keys()) != newkeys:
27             cat_change += attr+"\n"
28         newdict = {key: val for key, val in zip(newkeys, self.
29             metadata[attr]['values'].values())}
30         self.metadata[attr]['values'] = newdict
31     return cat_change[0:-1]
32
33     def encodecont(self):
34         pattern = r'(^|[^\\w])(niu|universe)([^\\w]|$)' # Raw string to
35         prevent invalid escape sequence '\\w'
36         pattern = re.compile(pattern, re.IGNORECASE)
37         cont_nonpos = ""
38         for attr in self.metadata.keys():
39             if self.metadata[attr]['type'] == 'Continuous':
40                 flag = False
41                 for strval in self.metadata[attr]['values'].keys():
42                     if not flag:
43                         try:
44                             if int(strval) <= 0:
45                                 text = self.metadata[attr]['values'][strval]
46                                 matches = re.search(pattern, text.replace(',',
47                                         ' ').lower())
48                                 if bool(matches):
49                                     flag = True
50                                     cont_nonpos += attr+"\n"
51                                     self.dataset[attr] = self.dataset[attr].
52                                         apply(lambda v: 0 if v < 0 else v)
53                                     break
54                                 except:
55                                     pass
56                                 if flag:
57

```

```

53         try:
54             if int(strval) <= 0:
55                 self.metadata[attr]['values'].pop(strval,
56                                         None)
56             except:
57                 pass
58             if flag:
59                 self.metadata[attr]['values']['0'] = 'NIU'
60     return cont_nonpos[0:-1]

```

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

```

1 import pandas as pd
2
3 # Delete the accessor to avoid warning
4 51
4 try:
5     del pd.DataFrame.info
6 except AttributeError:
7     pass
8
9 @pd.api.extensions.register_dataframe_accessor("info")
10 class Info:
11     def __init__(self, pandas_obj):
12         self._validate(pandas_obj, ['id', 'variable', 'type', 'min', 'max'])
13         49
13         self.dataset = pandas_obj
14
15     @staticmethod
16     def _validate(obj, cols):
17         if any(x not in obj.columns for x in cols):
18             raise AttributeError("Some attributes are missing")
19
20     def setcut(self, pcont, pcatmax):
21         self.dataset['cut'] = 0

```

```
22     self.dataset.loc[self.dataset['type'] == 'Continuous', 'cut'] =
23         pcont
24     self.dataset.loc[self.dataset['type'] == 'Categorical', 'cut'] =
25         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, PEAPEVER, PEDISDRS, PEDISEAR, PEDISEYE, PEDISOUT, PEDISPHY, PEDISREM, PRDISFLG, PRCTSHP, PRDTRACE
Basic CPS items	Edited labor force items <sup>95</sup>	A_MJIND, A_MJOC, PEI01COW, PRDISC, PRUNTYPE <sup>17</sup>
	Edited earnings items	A_GRSWK, A_HRLYWK, A_HRSPAY, PRRELG
	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, NWLWKW, 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_SCI, DIS_SC2, DIS_VAL1, DIS_VAL2, DIS_YN, DIV_VAL, DIV_YN, DSAB_VAL, DST_SC1, 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_SCI, PEN_SC2, PEN_VAL1, PEN_VAL2, PEN_YN, PNSN_VAL, PTOTVAL, RESNSS1, RESNSS2, RESNSS1L, RESNSS2, RETCB_VAL, RETCB_YN, RINT_SCI, RINT_SC2, RINT_VAL1_RINT_VAL2, RINT_YN, RNT_VAL, RNT_YN, SRV\$_VAL, SS_VAL, SS_YN, SSL_VAL, SSL_YN, STRKUC, SUBUC, SUR_SCI, 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, <sup>29</sup> FEDTAX_AC_FEDTAX_BC_FICAFILESTAT_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	NY_	Y1Y	YNN
<b>A AGE: Age</b>				
Universe: All Persons				
(-0.085, 8.5]	1,407	5,834	789	628
(8.5, 17.0]	1,557	6,237	1,079	770
(17.0, 25.5]	2,238	2,475	1,043	414
(25.5, 34.0]	2,635	2,749	1,082	594
(34.0, 42.5]	2,271	2,146	976	613
(42.5, 51.0]	2,109	2,171	1,157	518
(51.0, 59.5]	1,606	2,403	1,223	471
(59.5, 68.0]	1,028	4,854	2,313	2,090
(68.0, 76.5]	105	5,404	2,602	2,044
(76.5, 85.0]	79	4,472	1,977	1,353
				115

A\_EXPRRP: Expanded relationship code [12](#)

Universe: All Persons

Reference person with relatives

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	NY	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

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	NY	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	NY	NY_	Y1Y	YNN
High school graduate - high school diploma or equivalent <sup>1</sup>	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, A.B, 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 <sup>12</sup>					
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	NY	NY_	Y1Y
Separated	356	723	144	101
Never married	7,693	19,062	4,268	2,426
<b>A_PFREL: Primary family relationship</b> [12]				
Universe: All Persons				
Not in primary family	2,946	7,815	3,354	1,699
Husband	2,408	5,385	3,324	2,794
Wife	2,501	4,998	3,382	2,404
Own child	4,337	12,355	2,540	1,553
Other relative	1,328	4,659	784	436
Unmarried reference person	1,315	3,533	857	609
<b>A_SEX: Sex</b>				
Universe: All Persons				
Male	7,804	17,947	6,658	4,710
Female	7,231	20,798	7,583	4,785
<b>P_STAT: Status of person identifier</b>				

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	NY_	Y1Y	YNN
Universe: All Persons <sup>12</sup>	12,186	28,562	12,747	8,334
Civilian 15+	418	16	6	1
Armed forces				105
Children 0-14	2,431	10,167	1,488	1,160
PEAFEVER: Did you ever serve on active duty in the U.S. Armed Forces? <sup>4</sup>				17,629
Universe: A_ AGE greater than or equal to 17				
Not in universe	3,207	11,462	1,745	1,320
Yes	674	3,025	1,158	1,233
No	11,154	24,258	11,338	6,942
PEDISDAS: Does...have difficulty dressing or bathing?				57,291
Universe: PRPERTYP = 2				
Not in universe	2,849	10,183	1,494	1,161
Yes	98	1,545	299	233
No	12,088	27,017	12,448	8,101
PEDISEAR: Is...deaf or does ...have serious difficulty hearing? <sup>111</sup>				62,207

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	NY_	Y1Y	YNN	
<b>Universe: PRPERTYP = 2</b>					
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
<b>PEDISEYE: Is...blind or does...have serious difficulty seeing even when wearing glasses?</b>					
<b>Universe: PRPERTYP = 2</b>					
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
<b>PEDISOUT: Because of a physical, mental, or emotional condition, does...have difficulty doing errands along such as visiting a doctor's office or shopping?</b>					
<b>Universe: PRPERTYP = 2</b>					
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	NY_	Y1Y	YNN
No	11,963	25,406	12,109	7,821
<b>PEDISPHY: Does...have serious difficulty Walking or climbing stairs?</b>				
Universe: PRPERTYP = 2				
Not in universe	2,849	10,183	1,494	1,161
Yes	339	4,767	1,210	900
No	11,847	23,795	11,337	7,434
<b>PEDISREM: Because of a physical, mental, or emotional condition, does...have serious difficulty concentrating, remembering, or making decisions?</b>				
Universe: PRPERTYP = 2				
Not in universe	2,849	10,183	1,494	1,161
Yes	292	2,489	519	367
No	11,894	26,073	12,228	7,967
<b>PRDISTLG: Does this person have any of these disability conditions?</b>				
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
Yes	732	7,560	2,124	1,569
No	11,454	21,002	10,623	6,765
<b>PRCITSHIP: Citizenship group</b>				
Universe: All persons	11,006	32,887	12,065	8,403
Native, born in US	82	345	60	49
Native, born in PR or US outlying area	153	249	92	76
Native, born abroad of US parent(s)	1,004	2,975	1,067	650
Foreign born, US cit by naturalization	2,790	2,289	957	317
Foreign born, not a US citizen				3,968
<b>PRDTRACE: Race</b>				
Universe: All persons	11,466	27,682	11,885	7,517
White only	1,765	6,815	1,011	1,051
Black only	516	902	97	85
American Indian, Alaskan Native only (AI)	745	2,010	962	561
Asian only				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
Hawaiian/Pacific Islander only (HP)	89	192	34	41
White-Black	150	428	70	58
White-AI	131	351	81	96
White-Asian	86	111	52	41
White-HP	17	50	15	13
Black-AI	26	67	5	12
Black-Asian	2	8	9	3
Black-HP	1	8	1	4
AI-Asian	2	6	1	0
AI-HP	0	4	0	0
Asian-HP	5	17	12	7
White-Black-AI	13	44	2	3
White-Black-Asian	12	8	0	1
White-Black-HP	0	1	0	5
White-AI-Asian	2	3	0	7
White-AI-HP	0	3	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-Al-Asian	1	0	0	1	1
White-Black-Al-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 <span style="color: green;">A</span>					
Universe: A_CLSWKR = 1-7	6,704	30,326	8,393	5,873	29,260
Not in universe, or children	268	241	309	79	536
Agriculture, forestry,fishing, and hunting					
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	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\_MIOCC: Major occupation recode [4](#)  
 Universe: A\_CLSWKR = 1-7  
 Not in universe or children  
 Management, business, and financial occupations  
 Professional and related occupations  
 Service occupations  
 Sales and related occupations  
 Office and administrative support occupations

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	
<b>PEIOTCCW: Individual class of worker on first job</b> <sup>12</sup>						
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 <sup>12</sup>					
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	NY_	Y1Y	YNN
Re-entrant	162	266	62	38
New-entrant	39	84	7	6
<b>A – GRSWK:</b> How much does ... usually earn per week at this job before [redacted] 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
(288,5, 577,0]	412	407	218	112
(577,0, 865,5]	285	213	159	122
(865,5, 1154,0]	111	88	102	92
(1154,0, 1442,5]	64	47	42	36
(1442,5, 1731,0]	34	18	33	27
(1731,0, 2019,5]	21	15	20	16
(2019,5, 2308,0]	10	9	15	9
(2308,0, 2596,5]	13	6	20	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	NY_	Y1Y
(2596.5, 2885.0]	19	13	36
	36	36	638
<b>A_HRLYWk: Is ... paid by the hour on this job? <span style="color: red;">4</span></b>			
Universe: PRERELG=1			
Not in universe or children and armed forces			
Yes	13,245	37,057	13,105
	1,320	1,289	662
No	470	399	414
	312	312	6,154
<b>A_HRSPAY: How much does ... earn per hour? <span style="color: red;">6</span></b>			
Universe: A_HRLYWk=1			
(-10,901, 989.1]	14,314	38,046	13,813
(989.1, 1979.2]	563	582	312
(1979.2, 2969.3]	112	80	69
(2969.3, 3959.4]	28	24	20
(3959.4, 4949.5]	10	6	12
(4949.5, 5939.6]	5	4	10
(5939.6, 6929.7]	3	1	2
	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	NY_	Y1Y
(6929.7, 7919.8]	0	1	1
(7919.8, 8909.9]	0	0	0
(8909.9, 9900.0]	0	1	2
		0	4
PRERELG: Earnings eligibility flag <sup>12</sup>			
Universe: All persons			
Not earnings eligible	13,245	37,057	13,165
Earnings eligible	1,790	1,688	1,076
A_CIVLF: Civilian labor force			
Universe: All persons			
Not in universe or children and Armed Forces	<sup>104</sup> 6,798	30,466	8,496
In universe	8,237	8,279	5,745
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
Private	6,488	6,417	3,692	2,576
Federal government	222	120	57	138
State government	189	237	151	213
Local government	219	337	196	296
Self-employed-incorporated	325	323	756	152
Self-employed-not incorporated	880	974	986	246
Without pay	8	11	10	1
Never worked	39	84	7	7
			6	74

A_EXPLF: Experienced labor force employment status	<sup>16</sup>
Universe: PEMPLR=1-4	
Not in experienced labor force	6,837
Employed	30,550
Unemployed	7,506
	5,471
	898
A_LFSR: Labor force status recode	
Universe: All persons	
692	267
	187
	1,632

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
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	4,739	11,854

A\_UNCOV: On this job, is ... covered by a union or employee association <sup>15</sup> contract?

Universe: A\_UNMEM=2

Not in universe or children and armed forces

Yes

No

	NNN	NNY	NY_	Y1Y	YNN
13,962	37,715	13,483	9,016	72,936	
8	11	8	10	108	
1,065	1,019	750	469	7,121	

A\_UNMEM: On this job, is ... a member of a labor union or of an employee <sup>6</sup> 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 <span style="color:red;">-</span>	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 <span style="color:green;">4</span>					
Universe: A_LFSR = 3 or 4					
Not in universe or children and Armed Forces					
Job loser - on layoff	14,304	37,763	13,967	9,302	78,459
Other job loser	252	341	136	72	797
Job leaver	209	227	55	66	422
Re-entrant	69	64	14	11	138
New entrant	162	266	62	38	275
A_USLHRS: How many hrs per week does ... usually work at this job? <span style="color:green;">4</span>					
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
<b>A_WKSCH: Labor force by time worked or lost</b>					
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	NY	Y1Y	YNN
<b>A_WKSK: Duration of unemployment</b> <span style="color: #800000;">6</span>				
Universe: PEMLR=3 or 4				
(-0.099, 9.9]	14,748	38,340	14,142	9,435
(9.9, 19.8]	118	150	44	27
(19.8, 29.7]	49	76	17	12
(29.7, 39.6]	26	50	9	7
(39.6, 49.5]	10	11	4	4
(49.5, 59.4]	45	50	11	5
(59.4, 69.3]	9	10	3	0
(69.3, 79.2]	4	2	0	0
(79.2, 89.1]	0	0	0	1
(89.1, 99.0]	26	56	11	5
			31	

A\_WKSTAT: Full/part-time status 12

Universe: All persons

Children or Armed Forces

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	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	8,336	32,561	9,610	6,541	34,614
(-4,144, 10,4]	595	1,159	671	330	2,447
(10,4, 24,8]	1,147	1,420	805	444	4,613
(24,8, 39,2]	4,519	3,253	2,721	1,976	35,068
(39,2, 53,6]	333	257	306	147	2,691
(53,6, 68,0]	87	76	102	42	583
(68,0, 82,4]					

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
(82.4, 96.8]	14	7	12	8
(96.8, 111.2]	4	11	13	7
(111.2, 125.6]	0	0	1	0
(125.6, 140.0]	0	1	0	0
PEMLR: Major labor force recode				
Universe: All persons				
NIU	2,849	10,183	1,494	1,161
Employed - at work	7,178	6,826	5,136	3,181
Employed - absent	328	471	335	161
Unemployed - on layoff	252	341	136	72
Unemployed - looking	479	641	138	121
Not in labor force - retired	543	11,004	5,087	3,754
Not in labor force - disabled	437	4,110	405	359
Not in labor force - other	2,969	5,169	1,510	686
PRCOW1: Class of worker recode-job 1	135			

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	NY_	Y1Y	YNN	
<b>Universe: All persons</b> <span style="color: blue;">12</span>					
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
<b>PRPTRE: Detailed reason for part-time</b> <span style="color: blue;">15</span>					
Universe: Part time workers	<span style="color: blue;">20</span>				
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	NY_	Y1Y	YNN	
Usually FT - own illness/injury/medical aptt	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	NY_	Y1Y
Usually PT - retired/social security limit on earnings <sup>1</sup>	52	440	238
Usually PT - workweek<35 hours	260	407	106
Usually PT - other	107	145	58
PRWKSTAT: Full/part-time work status			
Universe: All persons			
NIU	2,849	10,183	1,494
Not in labor force	3,949	20,283	7,002
FT hours (35+), usually FT	4,995	3,679	3,226
PT for economic reasons, usually FT <sup>15</sup>	267	217	153
PT for non-economic reasons, usually FT <sup>15</sup>	436	401	254
Not at work, usually FT	227	238	179
PT hrs, usually PT for economic reasons <sup>15</sup>	324	377	140
PT hrs, usually PT for non-economic <sup>15</sup>	1,099	2,080	1,308
FT hours, usually PT for economic reasons <sup>15</sup>	17	16	12
FT hours, usually PT for non-economic reasons <sup>15</sup>	40	56	43

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	NY_	Y1Y	YNN
Not at work, usually part-time <sup>–</sup>	101	233	156	56
Unemployed FT <sup>–</sup>	618	722	197	136
Unemployed PT <sup>–</sup>	113	260	77	57
CLWK: Longest job class of worker (recode) <sup>6</sup>				
Universe: All persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Private <sup>–</sup>	6,959	7,099	4,733	3,023
Government <sup>–</sup>	1,009	747	446	710
Self-employed <sup>–</sup>	849	992	1,008	253
Without pay <sup>–</sup>	17	12	15	15
Never worked <sup>–</sup>	3,770	19,728	6,551	4,348
EARNER: Earner status recode				
Universe: All persons aged 15+				
Niu	2,431	10,167	1,488	1,160
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	NY_	Y1Y	YNN
Nonearner	3,783	19,736	6,565	4,349
HRSWK: In the weeks that ... worked how many hours did ... usually work per week? <span style="background-color: #e6f2ff; border: 1px solid black; padding: 2px;">6</span>				
Universe: WKSWORK > 0				
(-0.099, 9.9]	6,347	30,317	8,296	5,648
(9.9, 19.8]	354	837	443	259
(19.8, 29.7]	875	1,550	858	390
(29.7, 39.6]	1,277	1,534	847	486
(39.6, 49.5]	5,110	3,719	2,826	2,191
(49.5, 59.4]	673	461	578	336
(59.4, 69.3]	276	228	263	122
(69.3, 79.2]	77	48	74	33
(79.2, 89.1]	41	33	33	20
(89.1, 99.0]	5	18	23	10
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	NY_	Y1Y	YNN	
<b>Universe: WKSWORK &gt; 0</b>					
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
<b>NWLKWK: How many different weeks was ... looking for work or on layoff?</b>					
Universe: NWLOOK = 1	14,892	38,462	14,188	9,469	79,995
(-0.052, 5,2]	15	32	7	6	38
(5,2, 10,4]	13	29	4	0	17
(10,4, 15,6]	7	17	4	2	9
(15,6, 20,8]					

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

NWLLOOK: Even though ... did not work in 20.. did spend and time trying to [4](#)

find a job or on layoff?

Universe: WORKYN = 2

Niu

Yes

No

	NNN	NNY	NY_	Y1Y	YNN
	11,265	19,017	7,690	5,147	69,988
	176	340	70	41	236
	3,394	19,388	6,481	4,307	9,941

PHMEMPRS: For how many employers did... work in 20..? if more than one [6](#)

at same time, only count it as one employer

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..? <sup>4</sup>	
Universe: WORKYN = 2	
Niu	11,265
Ill or disabled	508
Retired	477
Taking care of home	1,331
Going to school	1,043
Could not find work	209
Other	202

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+	2,431	10,167	1,488	1,160	17,629
Niu	5,641	3,827	3,519	2,265	41,178
Full-year worker (Full time)	1,027	1,832	1,095	515	3,717
Full-year worker (Part time)					

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) <sup>99</sup>	1,259	1,434	695	716	4,156	
Part-year worker (Part time) <sup>100</sup>	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? <sup>101</sup>

(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	NY_	Y1Y	YNN
(46,8, 52,9]	6,846	5,885	4,776	2,898
<b>WORKYN: Did ... work at a job or business at any time during 20...? <span style="color:red">12</span></b>				
Universe: All persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	8,727	8,684	6,108	3,938
No	3,877	19,894	6,645	4,397
<b>WRK_CFK: Worked last year recode, including temporary and part-time <span style="color:red">1</span></b>				
Universe: All persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	8,884	8,850	6,202	3,987
No	3,770	19,728	6,551	4,348
<b>WTEMP: Did ... do any temporary, part-time, or seasonal work even for a few <span style="color:green">4</span> days during 20...?</b>				
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	NY_	Y1Y	YNN
Yes	107	166	94	49
No	3,770	19,728	6,551	4,348
<b>ERN_OTR: Wage and salary money earned from other work, Y/N</b>				
Universe: All persons aged 15+				
Niu	6,201	29,895	8,039	5,508
Yes	819	847	635	496
No	8,015	8,003	5,567	3,491
<b>ERN_SRC: Source of earnings from longest job</b>				
Universe: ERN_YN = 1				
Niu	6,201	29,895	8,039	5,508
Wage and salary	7,968	7,846	5,179	3,733
Self employment	809	940	904	224
Farm self employment	40	52	104	29
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	NY_	Y1Y	YNN
ERN_VAL: How much did ... earn from this employer before deductions in <sup>4</sup> 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
(101000.8, 212000.6]	239	156	378	286
(212000.6, 323000.4]	22	24	56	54
(323000.4, 434000.2]	9	11	18	16
(434000.2, 545000.0]	6	6	13	6
(545000.0, 655999.8]	3	3	7	0
(655999.8, 766999.6]	1	0	4	1
(766999.6, 877999.4]	2	0	4	1
(877999.4, 988999.2]	1	0	1	1
(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
<b>ERN_YN: Earnings from employer or net earnings from business / farm after expenses from longest job during 20..?</b>				
Universe: WORKYN=1 or WTEMP=1				
Niu	2,431	10,167	1,488	1,160
Yes	8,817	8,838	6,187	3,986
No	3,787	19,740	6,566	4,349
<b>FRM_VAL: Amount of farm self-employment earnings from secondary source</b>				
Universe: FRMOTR = 1				
(-10288.999, 19000.9]	15,028	38,744	14,230	9,484
(19000.9, 48000.8]	3	1	7	3
(48000.8, 77000.7]	3	0	0	5
(77000.7, 106000.6]	1	0	4	3
(251000.1, 280000.0]	0	0	0	1
<b>FRMOTR: Receiving farm self-employment from secondary source</b>				
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
Niu	14,212	37,902	13,606	9,002
Yes	86	56	73	43
No	737	787	562	450
	4,686			

FRSE_VAL: Total amount of farm self-employment earnings <span style="color:red;">=</span>	Universe: ERN_YN=1 or FRMOTR=1	15,029	38,739	14,206	9,483	80,136
(-20767.998, 57001.8]		6	5	29	10	25
[57001.8, 134001.6]		0	1	2	0	3
(134001.6, 211001.4]		0	0	3	1	1
[211001.4, 288001.2]		0	0	0	1	0
(442000.8, 519000.6]		0	0	0	0	0
(673000.2, 750000.0]		0	0	1	0	0

FRSE_YN: Receiving any farm self-employment <span style="color:red;">=</span>	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	NY_	Y1Y	YNN
No	12,482	28,473	12,583	8,265
PEARNVAL: Total persons earnings				
Universe: All persons aged 15+				
(-12083.998, 198500.8]	14,962	38,669	14,069	9,370
(198500.8, 407000.6]	53	62	126	111
(407000.6, 615500.4]	11	11	22	8
(615500.4, 824000.2]	3	0	10	2
(824000.2, 1032500.0]	3	2	5	3
(1032500.0, 1240999.8]	3	1	8	1
(1240999.8, 1449499.6]	0	0	1	0
(1449499.6, 1657999.4]	0	0	0	1
(1866499.2, 2074999.0]	0	0	0	1

SE\_VAL: Amount of own business self-employment earnings from secondary = 1

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 [12](#))

in ern-val, if ern-srce=2, and sc-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 <span style="color:red;">-</span>					
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 <span style="color:red;">-</span>					
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	NY_	Y1Y	YNN
No	673	692	463	394
<b>WAGEOTR: Receiving wage and salary earnings from other employers, Y/n</b>				
Universe: ERN_OTR = 1				
Niu	14,218	37,901	13,607	9,002
Yes	786	807	590	471
No	31	37	44	22
				244
<b>WS_VAL: Amount of wage and salary earnings from other employers</b>				
Universe: ERN_OTR = 1				
(-1099.999, 10999.9]	15,033	38,738	14,235	9,491
(10999.9, 21999.8]	1	7	5	3
(21999.8, 32999.7]	1	0	1	3
(32999.7, 43999.6]	0	0	0	5
(43999.6, 54999.5]	0	0	0	1
(87999.2, 98999.1]	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	NY_	Y1Y	YNN
(989999.1, 1099999.0]	0	0	0	2
<b>WSAL_VAL:</b> Total wage and salary earnings (combined amounts in ern-val, if <span style="background-color: #e67e22; color: white;">6</span> )				
ern-srce=1, and rs-val)				
Universe: ERN_YN=1 or WAGEOTR=1				
(-1999.99, 199999.9]	14,976	38,684	14,113	9,393
(19999.9, 399999.8]	38	44	85	87
(39999.8, 599999.7]	13	13	25	9
(59999.7, 799999.6]	3	1	4	1
(79999.6, 999999.5]	3	0	4	2
(99999.5, 1199999.4]	2	3	10	3
(119999.4, 1399999.3]	0	0	0	1
(179999.1, 1999999.0]	0	0	0	1
<b>WSAL_YN:</b> Receiving wage and salary earnings <span style="background-color: #e67e22; color: white;">-</span>				
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	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
<b>ANN_VAL: Retirement income, annuities amount</b>					
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
<b>ANN_YN: Retirement income, annuities, y/n</b>					
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
No	12,578	27,944	12,180	7,913
CAP_VAL: Capital gains value				
Universe: CAP_YN = 1				
(-999,999, 99999,9]	15,031	38,725	14,211	9,473
(99999,9, 19999,8]	2	13	16	16
[19999,8, 29999,7]	2	6	6	5
(29999,7, 39999,6]	0	1	3	0
(39999,6, 49999,5]	0	0	1	0
(49999,5, 59999,4]	0	0	1	1
(69999,3, 79999,2]	0	0	1	0
(89999,1, 99999,0]	0	0	2	2
CAP_YN: Yes/no answer to "Did 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	NY_	Y1Y	YNN
Yes	176	734	958	693
No	815	1,937	1,920	1,268
<b>DBTN_VAL: Total amount of retirement distributions received (dst_val1 + dst_val2)</b>				
Universe: DST_VAL1>0 OR DST_VAL2>0	15,033	38,711	14,203	9,460
(-999.999, 99999.9]	2	32	35	32
(99999.9, 199999.8]	0	2	2	1
(199999.8, 299999.7]	0	0	0	0
(299999.7, 399999.6]	0	0	1	0
(399999.6, 499999.5]	0	0	0	1
(899999.1, 999999.0]	0	0	1	0
<b>DIS_SC1: What was the source of disability income? =</b>				
Universe: DIS_YN=1	14,947	38,270	14,130	9,359
Niu	16	32	11	15
Worker's compensation				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

Federal government disability

Us military retirement disability

State or local gov't employee disability

	NNN	NNY	NY_	Y1Y	YNN
	15,035	38,740	14,240	9,493	80,158

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	NY_	Y1Y	YNN
Other or don't know <sup>15</sup>	0	2	0	1
DIS_VAL1: How much did ... receive (source type) during 20..? <sup>16</sup>				
Universe: DIS_SC1>0				
(-100,0,10000.0]	14,993	38,533	14,185	9,428
(10000.0, 20000.0]	26	144	25	31
(20000.0, 30000.0]	7	33	16	23
(30000.0, 40000.0]	4	13	4	4
(40000.0, 50000.0]	3	10	1	2
(50000.0, 60000.0]	1	0	0	1
(60000.0, 70000.0]	1	1	1	0
(70000.0, 80000.0]	0	1	1	4
(80000.0, 90000.0]	0	1	0	1
(90000.0, 100000.0]	0	9	8	4
DIS_VAL2: How much did ... receive (source type) during 20..? <sup>16</sup>				
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, 23672]	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 <span style="background-color: red; color: white;">-</span>					
result of health problems?					
Universe: All Persons aged 15+					
Nu	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 <span style="background-color: cyan; color: black;">x</span>					
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 <span style="background-color: red;">-</span>					
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
(10000.0, 20000.0]	26	147	25	32
(20000.0, 30000.0]	7	33	17	23
(30000.0, 40000.0]	4	14	4	3
(40000.0, 50000.0]	3	10	1	2
(50000.0, 60000.0]	1	0	0	2
(60000.0, 70000.0]	1	1	1	0
(70000.0, 80000.0]	0	1	1	1
(80000.0, 90000.0]	0	1	0	1
(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: Retirement Distribution source 1, person under age 58 <span style="color:red;">=1</span>					
Universe: DST_YN_YNG = 1 and a_age < 58 <span style="color:red;">=1</span>	14,950	38,651	14,163	9,424	79,246
Niu	52	60	45	47	653
401k account	4	3	3	4	41
403b account	13	11	5	7	66
Roth ira	11	15	20	4	107
Regular ira					
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: Retirement 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
<b>DST_VAL1: Retirement income amount, distribution source 1</b>					
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
<b>DST_VAL1_YNG: Retirement Distribution amount 1, under age 58</b>					
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
(89999.1, 99999.0]	0	0	0	0
<b>DST_VAL2: Retirement income amount, distribution source 2</b>				
Universe: DST_SC2 = 1				
(-75.0, 7500.0]	15,034	38,719	14,208	9,469
(7500.0, 15000.0]	1	20	21	15
(15000.0, 22500.0]	0	0	3	2
(22500.0, 30000.0]	0	0	1	0
(30000.0, 37500.0]	0	1	1	0
(37500.0, 45000.0]	0	0	1	1
(45000.0, 52500.0]	0	1	0	0
(52500.0, 60000.0]	0	1	4	1
(60000.0, 67500.0]	0	2	0	0
(67500.0, 75000.0]	0	1	2	0
<b>DST_VAL2_YNG: Retirement Distribution amount 2, under age 58</b>				
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) <span style="color:red;">■</span>					
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: Retirement Distribution Recipency, person under age 58 <span style="color:red;">■</span>					
Universe: Persons under age 58 (a_age < 58) <span style="color:red;">■</span>					
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
<b>ED_VAL: Total amount of educational assistance received (combined amounts in pell grant and other educational) assistance during 20..?</b>					
Universe: ED_YN = 1					
(-99,999, 999,9]	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

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
Universe: All Persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	430	611	303	159
No	12,174	27,967	12,450	8,176
60,390				
FIN_VAL: How much did ... receive in financial assistance income during 20.. <span style="color: red;">A</span>				
?				
Universe: FIN_YN = 1				
(-500, 50000.0]	15,033	38,742	14,238	9,491
(50000.0, 100000.0]	2	3	3	4
(100000.0, 150000.0]	0	0	0	0
(450000.0, 500000.0]	0	0	0	1
80,147				
FIN_YN: Did ... receive financial assistance?				
Universe: All Persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	166	321	141	75
				406
				182

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, 280000,0]	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

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
<b>OED_TYP1:</b> Source 1 other than gi bill received (OED_TYP1- source of other <span style="background-color: red;">-</span> 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
<b>OED_TYP2:</b> Source 2 other than gi bill received (OED_TYP2- scholarships, <span style="background-color: red;">-</span> 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
<b>OED_TYP3: Source other than gi bill received (OED_TYP3-other assistance - (employers friends, etc.)</b>				
Universe: ED_YN = 1				
Niu	14,584	38,089	13,928	9,331
Yes	51	51	41	26
No	400	605	272	138
				1,617
<b>OI_OFF: Other income sources</b>				
Universe: OI_YN = 1				
Niu	14,824	38,368	14,077	9,332
Social security	1	2	1	0
Private pensions	0	5	3	3
Aid/c	6	6	3	0
Other public assistance	0	2	0	1
Dividends	0	1	0	0
Rents or royalties	2	1	3	0
				7
				185

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) <sup>138</sup>	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
OL_VAL: How much did ... receive in other incomes <sup>6</sup>					
Universe: OL_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

OL\_YN: Did ... receive cash income not already covered from any other source?<sup>139</sup>

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 n/a	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
<b>PEN_SC2: Retirement income, pension source 2</b>					
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
<b>PEN_VAL1: Retirement income amount, pension source 1</b>					
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
(36000.0, 72000.0]	38,737
(72000.0, 108000.0]	14,239
(108000.0, 144000.0]	9,485
(324000.0, 360000.0]	80,158

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
Yes	173	2,710	1,847	2,188
No	12,431	25,868	10,906	6,147
<b>PNSN_VAL:</b> 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
(99999.9, 199999.8]	5	22	17	36
(199999.8, 299999.7]	0	3	1	3
(299999.7, 399999.6]	0	4	1	1
(399999.6, 499999.5]	0	3	1	0
(599999.4, 699999.3]	0	2	0	0
(699999.3, 799999.2]	0	1	0	0
(899999.1, 999999.0]	0	3	2	4
<b>PTOTVAL:</b> 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, 1456933.1]	0	0	2	0	8
(1456933.1, 1666563.4]	0	0	0	0	1
(1876133.7, 2085704.0]	0	0	1	0	2

RESNSSL: What were the reasons (you /name) (was/were) getting Social <sup>xx</sup>

Security Income last year?

Universe: SS YN = 1

Niu

Retired

Disabled (adult or child)

	NNN	NNY	NY_	Y1Y	YNN
	14,638	25,268	8,599	5,024	78,937
	195	10,639	5,128	3,924	693
	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 <sup>co</sup>	N/A	15,018	38,345	14,129	9,409	80,099
Security Income last year?		2	164	28	20	7
Universe: SS_YN = 1		0	103	50	31	3
N/A		3	20	4	4	3
Disabled (adult or child)		0	5	2	0	3
Widowed		0	4	0	0	2
Spouse						
Surviving child						
Dependent child						

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	NY_	Y1Y	YNN
On behalf of surviving, dependent, or disabled child(ren) <sup>-1</sup>	11	89	22	21
Other (adult or child)	1	15	6	10
RESNSS1: What were the reasons (you/name) (was/were) getting <sup>88</sup>				47
Supplemental Security Income last year?				
Universe: SSI_YN = 1				
Niu	14,976	36,504	14,140	9,303
Disabled (adult or child)	39	1,992	77	159
Blind (adult or child)	0	25	2	1
On behalf of a disabled child <sup>15</sup>	16	58	6	10
On behalf of a blind child <sup>15</sup>	0	2	0	0
Other (adult or child)	4	164	16	22
RESNSS12: What were the reasons (you/name) (was/were) getting <sup>88</sup>				16
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 contribution, 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
<b>RETCB_YN: Retirement contribution, y/n</b>				
Universe: All people 15 years and over				
Niu	13,470	34,901	10,249	6,228
Yes	1,034	793	1,070	1,247
No	531	3,051	2,922	2,020
<b>RINT_SC1: Interest income, retirement source 1</b>				
Universe: RINT_YN = 1				
Niu	13,470	34,901	10,249	6,228
401k account	973	1,925	1,791	1,791
403b account	60	121	118	188
Roth ira	216	421	583	292
Regular ira	163	1,063	1,207	711
Keogh plan	0	5	11	4
Sep plan (simplified employee pension)	19	49	98	43
Other type of retirement account	134	260	184	238
				1,699
				195

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
<b>RINT_SC2: Interest income, retirement source 2</b>					
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
<b>RINT_VAL1: Interest income amt, retirement source 1</b>					
Universe: RINT_SC1 > 0					
(-100,0, 100000.0]	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 <a href="#">4</a>					
20..?					
Universe: RNT_YN = 1					
(-11008.998, 91000.8]	15,031	38,718	14,217	9,473	80,117
(91000.8, 132000.6]	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
(394000.2, 495000.0]	0	0	1	1
(495000.0, 595999.8]	0	0	0	1
(595999.8, 696999.6]	1	0	0	1
(898999.2, 999999.0]	0	0	3	1
RNT_YN: Did ... own any land, property, rented to others, or receive income from royalties, roomers or boarders, or from estates or trusts?				2
Universe: All Persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	290	918	1,088	677
No	12,314	27,660	11,665	7,658
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)				59,734
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..? <span style="color: red;">4</span>					
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
(40000.0, 48000.0]	8	279	136	107
(48000.0, 56000.0]	0	3	1	0
(56000.0, 64000.0]	0	0	0	1
(72000.0, 80000.0]	0	2	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
Yes	397	13,477	5,642	4,471
No	12,297	15,101	7,111	3,864
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
(5000.0, 10000.0]	35	1,032	35	77
				47
				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
(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? <sup>4</sup>					
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
No	12,600	28,568	12,750	8,331
SUBUC: At any time during 20.. did ... receive any supplemental unemployment benefit? <sup>4</sup>				
Universe: UC_YN = 1				
Niu	2,431	10,167	1,488	1,160
Yes	11	28	9	8
No	12,593	28,550	12,744	8,327
SUR_SC1: What was the source of this other widow or survivor income? <sup>20</sup>				
Universe: SUR_YN = 1				
None or n/a	14,986	38,246	13,934	9,233
Company or union survivor pension	10	206	134	106
Federal government	7	49	25	41
Us military retirement survivor pension	2	48	10	10
State or local gov't survivor pension	3	44	34	39
Us railroad retirement survivor pension	2	14	6	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	NY	Y1Y	YNN
Worker compensation survivor	0	2	0	3
Black lung	0	1	0	1
Regular payments from estates or trusts	8	40	34	17
Regular payments from annuities or paid-up life insurance	6	29	30	15
Other or don't know	11	66	34	28
SUR_SC2: What was the source of this other widow or survivor income?				
Universe: SUR_YN = 1	15,034	38,731	14,233	9,490
None or min	0	2	0	0
Federal government	1	2	0	1
Us military retirement survivor pension	0	2	3	1
State or local gov't survivor pension	0	1	0	0
Worker compensation survivor	0	0	0	0
Black lung	0	0	1	0
Regular payments from estates or trusts	0	0	1	1
Regular payments from annuities or paid-up life insurance	0	5	1	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	NY	Y1Y	YNN
Other or don't know 15	0	2	3	0
<b>SUR_VAL1: How much did ... receive (survivor source type) during 20..? -1</b>				
Universe: SUR_YN = 1	15,009	38,539	14,106	9,366
(-100.0, 10000.0]	13	137	78	56
(10000.0, 20000.0]	6	35	25	36
(20000.0, 30000.0]	1	5	14	11
(30000.0, 40000.0]	3	14	5	10
(40000.0, 50000.0]	1	3	3	4
(50000.0, 60000.0]	0	0	1	1
(60000.0, 70000.0]	0	1	2	0
(70000.0, 80000.0]	2	11	7	11
(90000.0, 100000.0]	21			
<b>SUR_VAL2: How much did ... receive (source type) during 20..? -1</b>				
Universe: SUR_YN = 1	15,035	38,741	14,237	9,493
(-100.0, 10000.0]				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, excluding retirement 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..? <span style="color: red;">4</span>					
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
(49999.5, 59999.4]	0	1	3	2
(69999.3, 79999.2]	0	0	0	1
(89999.1, 99999.0]	0	0	0	1

UC_YN: Any type of unemployment compensation? (Combination of subuc, strkuc, and uctot_yn)	Universe: UC_YN = 1	Universe: VET_YN = 1
Niu	2,431	10,167
Yes	180	305
No	12,424	28,273

VET_TYP1: What type of veterans payments did .... receive? (VET_TYP1- <sup>26</sup> disability compensation?)	Universe: VET_YN = 1
Niu	14,764
Yes	203

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	NY_	Y1Y	YNN
No	68	321	67	55
<b>VET_TYP2: What type of veterans payments did .... receive? (VET_TYP2_</b> 88 survivor benefits?)				
Universe: VET_YN = 1				
Niu	14,764	37,749	14,043	9,176
Yes	4	80	16	14
No	267	916	182	305
				394
<b>VET_TYP3: What type of veterans payments did .... receive? (VET_TYP3_</b> 26 veteran's pension?)				
Universe: VET_YN = 1				
Niu	14,764	37,749	14,043	9,176
Yes	76	245	41	42
No	195	751	157	277
				351
<b>VET_TYP4: What type of veterans payments did .... receive? (VET_TYP4_</b> 4 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
<b>Universe: VET_YN = 1</b>					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	14	18	3	7	24
No	257	978	195	312	375
<b>VET_TYP5: What type of veterans payments did ... receive? (VET_TYP5_</b>					
other veteran's payment(s)?					
<b>Universe: VET_YN = 1</b>					
Niu	14,764	37,749	14,043	9,176	79,766
Yes	8	33	11	7	12
No	263	963	187	312	387
<b>VET_VAL: How much did ... receive from veterans' administration during</b>					
20..?					
<b>Universe: VET_YN = 1</b>					
(-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? 6

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...? <sup>4</sup>					
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
<b>WC _ YN: During 20.. did ... receive any worker's compensation payments or other payments as a result of a job related injury or illness?</b>				
Universe: All Persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	55	92	37	48
No	12,549	28,486	12,716	8,287
<b>PAW _ TYP: What type of program did... receive CASH assistance? <span style="color:red;">-1</span></b>				
Universe: PAW _ YN = 1				
Niu	15,011	38,275	14,214	9,382
TANF / AFDC	14	327	13	51
Other	8	130	14	60
Both	2	13	0	2
<b>PAW _ VAL: How much did ... receive in public assistance or welfare during <span style="color:red;">6</span> 20..?</b>				
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 1  
assistance from a state or county welfare program such as (State program name  
fill)?

Universe: All Persons aged 15+  
Niu

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
Yes	24	470	27	113
No	12,580	28,108	12,726	8,222
<b>PENINCL: Was ... included in that plan?</b>				
Universe: PENPLAN = 1				
Niu	12,999	36,775	12,935	7,709
Yes	1,334	996	775	1,381
No	702	974	531	405
<b>PENPLAN: Other than social security did the employer or union that ... worked <sup>-1</sup> for in 20... have a pension or other type of retirement plan?</b>				
Universe: WRK_CK = 1				
Niu	6,201	29,895	8,039	5,508
Yes	2,036	1,970	1,306	1,786
No	6,798	6,880	4,896	2,201
<b>WICYN: Who received WIC?</b>				
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	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? <span style="color:red;">-1</span>					
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? <span style="color:red;">-1</span>					
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? <span style="color:red;">-1</span>					
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	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
<b>Universe: CHSP_YN = 1</b>					
(-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
<b>CSP_YN: Did ... receive child support payments?</b>					
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
<b>ACTC_CRD: Additional child tax credit</b>					

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
<b>Universe: Tax unit head or dependent filer</b>					
(-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]  
(224208.3, 458415.6]

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	
(458415.6, 692622.9]	14	21	33	21	21	325
(692622.9, 926830.2]	4	5	16	4	4	98
(926830.2, 1161037.5]	4	5	11	9	9	87
(1161037.5, 1385244.8]	0	0	4	2	2	56
(1395244.8, 1629452.1]	0	1	1	2	2	7
(1629452.1, 1863659.4]	0	0	1	0	0	1
(1863659.4, 2097866.7]	0	0	1	0	0	6
(2097866.7, 2332074.0]	0	0	1	0	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	NY_	Y1Y	YNN
(5245.6, 5901.3]	168	306	28	39
(5901.3, 6557.0]	116	188	17	17
<b>FED_RET: Federal retirement payroll deduction</b>				
Universe: Tax unit head or dependent filer				
(-16.9, 1690.0]	15,032	38,744	14,241	9,491
(1690.0, 3380.0]	0	0	0	0
(3380.0, 5070.0]	1	1	0	0
(5070.0, 6760.0]	2	0	0	1
(6760.0, 8450.0]	0	0	0	0
(8450.0, 10140.0]	0	0	0	2
(10140.0, 11830.0]	0	0	0	0
(15210.0, 16900.0]	0	0	1	0
<b>FEDTAX_AC: Federal income tax liability, after all credits</b>				
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	
(63805.6, 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	NY_	Y1Y	YNN
(49904.1, 55449.0]	0	0	0	0
<b>FILESTAT: Tax filer status</b>				
Universe: All persons				
Joint, both <65	4,721	3,600	2,931	1,621
Joint, one ><65 & one 65+	235	1,045	692	782
Joint, both 65+	67	3,601	2,693	2,660
Head of household	764	1,485	350	299
Single	4,246	5,595	3,652	1,956
Non-filer	5,002	23,359	3,923	2,177
<b>MARG_TAX: Marginal tax rate</b>				
Universe: Tax unit head or dependent filer				
(-0.037, 3.7]	9,196	31,832	8,644	5,356
(7.4, 11.1]	1,801	2,645	1,229	717
(11.1, 14.8]	3,127	2,994	2,557	1,813
(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	NY_	Y1Y	YNN
(22.2, 25.9]	174	259	404	403
(29.6, 33.3]	15	39	53	62
(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
(206.5, 413.0]	131	275	104	94
(413.0, 619.5]	175	312	141	101
(619.5, 826.0]	210	347	136	124
(826.0, 1032.5]	131	225	119	86
(1032.5, 1239.0]	352	504	210	178
(1239.0, 1445.5]	228	252	155	108
(1445.5, 1652.0]	292	336	238	161
(1652.0, 1858.5]	265	284	167	124
(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
<b>STATETAX_A: State income tax liability, after all credits =</b>					
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
<b>STATETAX_B: State income tax liability, before credits</b>					
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	NY_	Y1Y	YNN
(25335.4, 50670.8]	12	23	38	28
(50670.8, 76006.2]	6	3	12	4
(76006.2, 101341.6]	0	0	2	5
(101341.6, 126677.0]	0	1	4	0
(126677.0, 152012.4]	0	0	0	0
(152012.4, 177347.8]	0	0	0	0
(177347.8, 202683.2]	0	0	0	0
(202683.2, 228018.6]	0	0	0	0
(228018.6, 253354.0]	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 =1  
recode),

Universe: All persons

Not in poverty universe

Below poverty level

100 - 124 percent of the poverty level

125 - 149 percent of the poverty level

150 and above the poverty level

	NNN	NNY	NY_	Y1Y	YNN
29	173	9	37	46	
2,650	10,405	1,038	549	1,873	
872	3,558	448	302	898	
968	3,113	506	303	1,240	
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	NY_	Y1Y	YNN
Universe: All persons				
Not in poverty universe	29	173	9	37
In poverty universe	15,006	38,572	14,232	9,458
HEA: Health status				
Universe: All persons	4,703	8,539	4,173	2,207
Excellent	4,895	9,678	4,540	3,038
Very good	4,164	11,856	3,859	2,899
Good	1,039	6,158	1,247	1,007
Fair	234	2,514	422	314
Poor				430
SPM_ACTC: SPM units Additional Child Tax Credit				
Universe: All persons	11,509	28,742	13,080	8,296
(-11.1, 1110.0]	1,538	3,848	513	507
(1110.0, 2220.0]	1,172	3,423	362	420
(2220.0, 3330.0]				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)

```

140 import os
2 import pandas as pd
3 import warnings
4
5 from module.utility import create_dir, import_dict
6 from module.eda import *
7 from module.dataset import *
8 from cls.ThesisExtension import *
9
10 texlive_binpath = '/usr/local/texlive/2024/bin/x86_64-linux'109
11 os.environ['PATH'] += os.pathsep + texlive_binpath
12
13 pd.set_option('display.max_columns', None)
14 pd.set_option('display.width', 1000)
15 warnings.filterwarnings('ignore')
16
17 # Given Information
18 dataset_name = "pppub20"
19
20 # Predefined Directories
21 meta_dir = "../../Data/Original/metadata"
22 feather_dir = "../../Data/Original/feather"
23 csv_dir = "../../Data/Original/csv"
24
25 output_dir = f"../../../../Outputs/Main/EDA/{dataset_name}"
26 log_dir = f"../../../../Logs/preprocessing"
27 log_filepath = f"{log_dir}/describe.log"
28
29 backup_dir = "../../../../Backups"
30
31 create_dir(log_dir)
32

```

```
33 # Data Preparation
34 indep_dict = import_dict(metadatapath=f'{meta_dir}/meta-indep.json')
35 depAttrs = ['GRP', 'DIR', 'PUB']
36 print()
37 describe_var(indep_dict)
38 print()
39 df = import_dataset(dataset_name=dataset_name, feather_dir=feather_dir)
40 print()
41 dep_features = ['class_orig', 'code_orig', 'code', 'class']
42 acpt_types = {'category', 'int16', 'int32', 'int8', 'uint16', 'uint32', '
    uint8'}
43 preprocess = True
44
45 if all(feat in df.columns for feat in dep_features):
46     col_types = set()
47     for col in df.columns:
48         col_types.add(str(df[col].dtype))
49     if col_types == acpt_types:
50         preprocess = False
51
52 if preprocess:
53     df.thesis.code(indep_dict, depAttrs)
54     df.thesis.recode()
55
56 filepath_feather = f'{feather_dir}/{dataset_name}.feather'
57 filepath_csv = f'{csv_dir}/{dataset_name}.csv'
58
59 if not os.path.isfile(filepath_feather):
60     export_dataset(df, file_dir='data/feather', dataset_name=dataset_name,
61                     format='feather')
62
63 if not os.path.isfile(filepath_csv):
64     dfther = pd.read_feather(filepath_feather)
65     export_dataset(dfther, file_dir='data/csv', dataset_name=dataset_name,
66                     format='csv')
```

```

66 # Univariate Data Analysis
67 df.thesis.show_type(option='full')
68 print()
69 df[['GRP','DIR','PUB','class_orig','code_orig','code','class']].
    drop_duplicates().sort_values('class').reset_index(drop=True)
70 print(f"Code: Employment-based plan (GRP) | Direct-purchase plan (DIR) |
        Public health insurance (PUB)")
71 print(df.groupby('code').size())
72 print('\n'*2)
73
74 # Cross Tabulation Analysis
75 print("-----")
76 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 attributes `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)

```

40
1 import os
2 import pandas as pd
3 import pyarrow
4
5 from module.utility import create_dir, import_dict, export_json,
    export_txt
6 from module.metaencode import *

```

```
7 from cls.Data import *
8
9 # Given Information
10 dataset_inname = "pppub20"
11 dataset_encname = f"{dataset_inname}enc"
12 dataset_procname = "proc20"
13
14 # Predefined Directories
15 meta_indir = "../../Data/Original/metadata"
16 meta_extra_indir = f"{meta_indir}/extra"
17 feather_indir = "../../Data/Original/feather"
18 csv_indir = "../../Data/Original/csv"
19
20 meta_encdir = "../../Data/Encoded/metadata"
21 meta_extra_encdir = f"{meta_encdir}/extra"
22 feather_encdir = "../../Data/Encoded/feather"
23 csv_encdir = "../../Data/Encoded/csv"
24 info_encdir = "../../Data/Encoded/info"
25
26 csv_procdir = "../../Data/Processed/csv"
27
28 create_dir(meta_extra_indir)
29 create_dir(feather_indir)
30 create_dir(csv_indir)
31 create_dir(meta_extra_encdir)
32 create_dir(feather_encdir)
33 create_dir(csv_encdir)
34 create_dir(info_encdir)
35 create_dir(csv_procdir)
36
37 # Metadata
38 indep_dict = import_dict(metadatapath=f"{meta_indir}/meta-indep.json")
39 export_json(extract_dict_cat(indep_dict), f"{meta_extra_indir}/meta-indep-
    cat.json")
40 export_json(extract_dict_cont(indep_dict), f"{meta_extra_indir}/meta-indep-
    cont.json")
```

```

41
42 # Imported Dataset
43 if os.path.isfile(f"{feather_indir}/{dataset_inname}.feather"):
44     df = pd.read_feather(f"{feather_indir}/{dataset_inname}.feather")
45     if not os.path.isfile(f"{csv_indir}/{dataset_inname}.csv"):
46         df.to_csv(f"{csv_indir}/{dataset_inname}.csv", index=False)
47 else:
48     df = pd.read_csv(f"{csv_indir}/{dataset_inname}.csv")
49
50 # Encoded Dataset and Dictionary
51 data_obj = Data(df.copy(), indep_dict.copy())
52 cat_var_change = data_obj.encodecat()
53 cont_var_nonpos = data_obj.encodecont()
54 df_enc = data_obj.dataset
55 indep_dict_enc = data_obj.metadata
56
57 # Processed Dataset
58 depAttrs = ['GRP', 'DIR', 'PUB']
59 classAttrs = ['class_orig', 'code_orig', 'code', 'class']
60 df_proc_enc = df_enc.drop(columns=['COV']+depAttrs+classAttrs)
61 df_proc_enc = sort_cols(df_proc_enc, indep_dict_enc).join(df_enc['class'])
62 df_proc_info = indep_info(df_proc_enc.loc[:, df_proc_enc.columns != 'class
   '], indep_dict_enc)
63 df_count_info = count_info(df_proc_info)
64
65 # Exported Results
66 df_enc.to_feather(f"{feather_encdir}/{dataset_encname}.feather")
67 df_enc.to_csv(f"{csv_encdir}/{dataset_encname}.csv", index=False)
68 export_json(
69     indep_dict_enc,
70     f"{meta_encdir}/meta-indep-{dataset_encname}.json"
71 )
72 export_json(
73     extract_dict_cat(indep_dict_enc),
74     f"{meta_extra_encdir}/meta-indep-cat-{dataset_encname}.json"
75 )

```

```

76
77 df_proc_enc.to_csv(f"{csv_procdir}/{dataset_procname}.csv", header=True,
    index=False)
78
79 df_proc_info.index = df_proc_info.index + 1
80 df_proc_info.to_csv(f"{info_encdir}/{dataset_encname}-info.csv",
    index_label="id")
81 df_count_info.to_csv(f"{info_encdir}/{dataset_encname}-countinfo.csv",
    header=True, index=False)
82
83 export_txt(cat_var_change, f"{meta_extra_encdir}/catchange-{{
    dataset_encname}.txt}")
84 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)

```

1 import pandas as pd
2 70 from functools import partial
3 from sklearn.feature_selection import mutual_info_classif, SelectKBest
4
5 from module.utility import create_dir
6
7 sel_num_ls = [3, 4, 8]
8 train_eachclass_num = 20
9

```

```

10 data_filepath = "../../Data/Processed/csv/proc20.csv"
11 info_filepath = "../../Data/Encoded/info/pppub20enc-info.csv"
12
13 data_selname = "selproc20"
14 train_name = "seltrain20"
15 test_name = "seltest20"
16
17 # Predefined Directories
18 sample_dir = "../../Samples/random"
19 sel_dir = f"{sample_dir}/{data_selname}"
20
21 data_dir = f"{sel_dir}/data"
22 info_dir = f"{sel_dir}/info"
23 feat_dir = f"{sel_dir}/features"
24 score_dir = f"{sel_dir}/scores"
25 train_dir = f"{sel_dir}/train"
26 test_dir = f"{sel_dir}/test"
27
28 54 create_dir(data_dir)
29 create_dir(info_dir)
30 create_dir(feat_dir)
31 54 create_dir(score_dir)
32 create_dir(train_dir)
33 create_dir(test_dir)
34
35 # Univariate Feature Selection
36 def feat_select(df_indata, df_info, sel_num):
37     discrete_feat_idx = df_info.index[df_info['type']=='Categorical']
38     77 score_func = partial(mutual_info_classif, discrete_features=
39         discrete_feat_idx)
40     feat_selector = SelectKBest(score_func, k=sel_num)
41     52 feat_selector.fit(df_indata.drop('class', axis=1), df_indata['class'])
42
43     df_scores = pd.DataFrame()
44     df_scores["Attribute"] = df_indata.drop('class', axis=1).columns
45     df_scores['Type'] = df_info['type']

```

```

45     df_scores["Support"] = feat_selector.get_support()
46     df_scores["F Score"] = feat_selector.scores_
47     df_scores["P Value"] = feat_selector.pvalues_
48
49     df_selfeat = df_scores[df_scores['Support']].drop('Support', axis=1).
50         reset_index(drop=True)
51
52     df_seldata = df_indata[df_selfeat['Attribute']].join(df_indata['class'
53         ])
54
55     minmax = df_seldata.loc[:, df_seldata.columns != 'class'].agg(['min',
56         'max']).values.tolist()
57     df_selfeat['Min'] = minmax[0]
58     df_selfeat['Max'] = minmax[1]
59     del minmax
60
61     return df_seldata, df_selfeat, df_scores
62
63 # Implementation
64 df_indata = pd.read_csv(data_filepath)
65 df_info = pd.read_csv(info_filepath)
66
67 print(f"\n{df_indata.head()}\n")
68 print(f"\n{df_info.head()}\n")
69
70 for sel_num in sel_num_ls:
71
72     # Univariate feature selection
73     df_seldata, df_selfeat, df_scores = feat_select(df_indata=df_indata,
74             df_info=df_info, sel_num=sel_num)
75
76     # Display results (selected features)
77     print(f"Select {sel_num} features:\n")
78     print(f"\n{df_selfeat}\n")
79
80     # Train-test split
81     df_seltrain = df_seldata.groupby('class', group_keys=False).apply(
82

```

```

77     lambda x: x.sample(train_eachclass_num)
78 )
79 df_seltest = df_seldata.drop(df_seltrain.index)
80
81 # Exported results
82 df_seldata.to_csv(f"{data_dir}/{data_selname}num{sel_num}.csv", header=
83     True, index=False)
84 df_selfeat.to_csv(f"{feat_dir}/fnum{sel_num}.csv", header=True, index=
85     False)
86 df_scores.to_csv(f"{score_dir}/snum{sel_num}.csv", header=True, index=
87     False)
88 df_selfeat.index = df_selfeat.index + 1
89 df_selinfo = df_selfeat.drop(['F Score', 'P Value'], axis=1)
90 df_selinfo.columns = ['variable', 'type', 'min', 'max']
91 df_selinfo.to_csv(f"{info_dir}/{data_selname}num{sel_num}info.csv",
92     index_label='id')
93 df_seltrain.to_csv(f"{train_dir}/{train_name}num{sel_num}each{
94     train_eachclass_num}.csv", header=True, index=False)
95 df_seltest.to_csv(f"{test_dir}/{test_name}num{sel_num}exc{
96     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)

```

1  42
1   import pandas as pd
2
3   from module.utility import create_dir
4   from cls.Info import *
5
6   # Given Information
7   pcut_ls = [2, 3]
8   info_ls = []
9   info_ls.append({
10      'indir': '../../Data/Encoded/info',
11      'infile': 'pppub20enc-info.csv',
12      'outdir': '../../Samples/proc20/cuts'
13  })
14 extra_infile_ls = [
15     "selproc20num3info.csv",
16     "selproc20num4info.csv",
17     "selproc20num8info.csv"
18 ]
19 for file in extra_infile_ls:
20     info_ls.append({
21         'indir': '../../Samples/selproc20/info',
22         'infile': file,
23         'outdir': '../../Samples/selproc20/cuts'
24     })
25 print(f"\n{info_ls}\n")
26
27 # Implementation
28 for dc in info_ls:
29     for pcut in pcut_ls:
30
31         # Import
32         inpath = f"{dc['indir']}/{dc['infile']}"
33         df = pd.read_csv(inpath)
34
35         # Set cuts
36         pcont, pcatmax = pcut, pcut

```

```
37     df.info.setcut(pcont, pcatmax)
38
39     # Set output path
40     infilename = dc['infile'].replace('.csv', '').replace('info', '').
41         replace('-', '')
42     cutfilename = f'{infilename}co{pcont}ca{pcatmax}cutinfo'
43     outpath = f'{dc['outdir']}/{cutfilename}.csv'
44
45     # Display results
46     print(f"Input: {inpath}")
47     print(f"Number of features: {len(df)}")
48     print(f"Number of continuous cuts: {pcont}")
49     print(f"Number of maximum categorical cuts: {pcatmax}")
50     print(f"Output: {outpath}\n")
51
52     # Export
53     create_dir(dc['outdir'])
54     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  $\tilde{x}^i = (\tilde{x}_j^i)_{1 \leq j \leq \tilde{d}} \in \mathbb{R}^{\tilde{d}}$  where  $1 \leq i \leq N$  has an integer class label between 0 and  $n$ . Let  $y_k^i$  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  $x^i = (x_j^i)_{1 \leq j \leq d} \in \mathbb{R}^d$  is a partial selection of the components of the original instance  $\tilde{x}^i$ :

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

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:  $b_{j,1} \leq \dots \leq b_{j,p_j}$ . Two endpoints are assumed:  $b_{j,0} = -M$  and  $b_{j,p_j+1} = M$  for sufficiently large positive  $M$  such as  $\max\{|x_j^i|\}$ . All splitting points along each new axis forms  $B = (p_1 + 1) \cdots (p_d + 1)$  decision boxes. A box  $S_\beta$  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,

$$\beta = \sum_{j=1}^{45} \left[ \prod_{j_0=0}^{j-1} (p_{j_0} + 1) \right] \left[ \sum_{q=0}^{107} q \beta_{j,q} \right]$$

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

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

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  $0 \leq q \leq p_j$ , and its existence is indicated by a boolean variable  $\alpha_{j,q}^i$ :

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

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

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

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

$$l_{j,q}^i \stackrel{73}{=} [-M, b_{j,q} + m_j] + M(1 - \alpha_{j,q}^i)$$

$$l_{j,q}^i \stackrel{73}{\in} [b_{j,q} + m_j, M] - M(1 - \alpha_{j,q}^i)$$

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

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

<sup>142</sup> *Proof.* It suffices to show that  $l_{j,q}^i = \alpha_{j,q}^i(b_{j,q} + m_j)$  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  $r_{j,q}^i$ . The equivalent condition for the nonlinear product is given by for sufficiently large positive  $M_1$ ,  $M_2$ ,  $M_3$  and  $M_4$

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

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

$$\begin{aligned} [b_{j,q} + m_j, M_3] &= [-M_1, 0] + [b_{j,q} + m_j + M_1, M_3] \\ [-M_4, b_{j,q} + m_j] &= [0, M_2] + [-M_4, b_{j,q} + m_j - M_2]. \end{aligned}$$

Hence the translations are given by  $(1 - \alpha_{j,q}^i)[b_{j,q} + m_j + M_1, M_3]$  and  $(1 - \alpha_{j,q}^i)[-M_4, b_{j,q} + m_j - M_2]$ . 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  $\gamma_\beta^i$ , an instance  $x^i \in \mathbb{R}^d$  is also located in one of these boxes labeled by  $0 \leq \beta \leq B - 1$ :

$$\begin{aligned} \sum_{j=1}^d \left[ \prod_{j_0=0}^{j-1} (p_{j_0} + 1) \right] \left[ \sum_{q=0}^{p_j} q \alpha_{j,q}^i \right] &= \sum_{\beta=0}^{B-1} \beta \gamma_\beta^i \\ \sum_{\beta=0}^{B-1} \gamma_\beta^i &= 1 \\ \gamma_\beta^i &\in \{0, 1\}. \end{aligned}$$

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

$$\Theta_\beta = \operatorname{argmax}_{0 \leq k \leq n} \left\{ \sum_{i=1}^N y_k^i \gamma_\beta^i \right\}.$$

In total, there are

$$N - \sum_{\beta=0}^{B-1} \max_{0 \leq k \leq n} \left\{ \sum_{i=1}^N y_k^i \gamma_\beta^i \right\} = N + h_\beta$$

misclassified instances where

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

**Theorem 4.2.** The optimal value of the program

$$\begin{aligned} & \text{minimize} \quad \sum_{\beta=0}^{B-1} h_\beta \\ & \text{subject to} \quad h_\beta + \sum_{i=1}^N y_k^i \gamma_\beta^i + N z_{\beta,k} \stackrel{10}{\geq} 0, \\ & \quad \sum_{k=0}^n z_{\beta,k} = n, \\ & \quad z_{\beta,k} \in \{0, 1\} \end{aligned}$$

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  $\mathcal{P}_{k_0}$ ,

$$h_\beta \geq - \sum_{i=1}^N y_{k_0}^i \gamma_\beta^i = 0 - \sum_{i=1}^N y_{k_0}^i \gamma_\beta^i \stackrel{128}{\geq} - \sum_{i=1}^N y_k^i \gamma_\beta^i - N z_{\beta,k}$$

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

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

$$\begin{aligned}
& b_{j,q+1} - b_{j,q} \geq 0, \\
& \sum_{j=1}^d \tilde{x}_j^i c_{j,j} - \sum_{j=1}^{p_j} l_{j,q}^i \geq 0, \\
& \sum_{j=1}^d \tilde{x}_j^i c_{j,j} - \sum_{q=0}^{10} r_{j,q}^i \leq 0, \\
& l_{j,q}^i + M\alpha_{j,q}^i \geq 0, \\
& l_{j,q}^i - M\alpha_{j,q}^i \leq 0, \\
& l_{j,q}^i - b_{j,q} + M\alpha_{j,q}^i \leq M + m_j, \\
& l_{j,q}^i - b_{j,q} - M\alpha_{j,q}^i \geq -M + m_j, \\
& r_{j,q}^i + M\alpha_{j,q}^i \geq 0, \\
& r_{j,q}^i - M\alpha_{j,q}^i \leq 0, \\
& r_{j,q}^i - b_{j,q+1} + M\alpha_{j,q}^i \leq M - m_j, \\
& r_{j,q}^i - b_{j,q+1} - M\alpha_{j,q}^i \geq -M - m_j, \\
& \sum_{j=1}^d \left[ \prod_{j_0=0}^{10} (p_{j_0} + 1) \right] \left[ \sum_{q=0}^{p_j} q\alpha_{j,q}^i \right] - \sum_{\beta=0}^{B-1} \beta\gamma_\beta^i = 0, \\
& \sum_{q=0}^{p_j} \alpha_{j,q}^i = 1, \\
& \sum_{\beta=0}^{B-1} \gamma_\beta^i = 1, \\
& h_\beta + \sum_{i=1}^N y_k^i \gamma_\beta^i + N z_{\beta,k} \geq 0, \\
& \sum_{k=0}^n z_{\beta,k} = n, \\
& l_{j,q}^i, r_{j,q}^i, b_{j,q}, h_\beta \in \mathbb{R}, \\
& c_{j,j}, \alpha_{j,q}^i, \gamma_\beta^i, z_{\beta,k} \in \{0, 1\}
\end{aligned}$$

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  $\tilde{x}_j^i \in \mathbb{R}$  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

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

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

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

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

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

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  $x_j^i \in \mathbb{R}$  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  $0 \leq \beta \leq B - 1$  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

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

$$\sum_{q=0}^{p_j} \beta_{j,q} = 1, \quad j \in \mathcal{C}_{\text{cont}}$$

$$\beta_{j,q} \in \{0, 1\}, \quad j \in \mathcal{C}_{\text{cont}}$$

$$u_j \in \{0, 1, \dots, p_j\}, \quad j \in \mathcal{C}_{\text{cat}}$$

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  $0 \leq v_{j,x_j^i} \leq p_j$ . As a result, the following conditions must hold:

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

$$\sum_{q=0}^{p_j} \alpha_{j,q}^i = 1, \quad j \in \mathcal{C}_{\text{cont}}$$

$$\sum_{\beta=0}^{B-1} \gamma_\beta^i = 1, \quad j \in \mathcal{C}_{\text{cont}}$$

$$\beta_{j,q} \in \{0, 1\}, \quad j \in \mathcal{C}_{\text{cont}}$$

$$v_{j,x_j^i} \in \{0, 1, \dots, p_j\}, \quad j \in \mathcal{C}_{\text{cat}}$$

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:

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

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

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

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

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

An original feature  $1 \leq \tilde{j} \leq \tilde{d}$  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  $v_{j, x^i}$  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:

$$\begin{aligned} & \text{minimize} \quad \sum_{\beta=0}^{B-1} h_\beta \\ & \text{subject to} \quad \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} c_{j, \tilde{j}} \leq 1, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad \sum_{j \in \mathcal{C}_{\text{cont}}} c_{j, \tilde{j}} \stackrel{(147)}{\leq} 1, \quad j \in \tilde{\mathcal{C}}_{\text{cont}}, \\ & \quad b_{j, q+1} - b_{j, q} \geq 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} \tilde{x}_j^i c_{j, \tilde{j}} - \sum_{q=0}^{p_j} l_{j, q}^i \geq 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad \sum_{\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}} \tilde{x}_j^i c_{j, \tilde{j}} - \sum_{q=0}^{p_j} r_{j, q}^i \leq 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad l_{j, q}^i + M \alpha_{j, q}^i \stackrel{(10)}{\geq} 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad l_{j, q}^i - M \alpha_{j, q}^i \leq 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad l_{j, q}^i - b_{j, q} + M \alpha_{j, q}^i \leq M + m_j, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad l_{j, q}^i - b_{j, q} - M \alpha_{j, q}^i \geq -M + m_j, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad r_{j, q}^i + M \alpha_{j, q}^i \geq 0, \quad j \in \mathcal{C}_{\text{cont}}, \\ & \quad r_{j, q}^i - M \alpha_{j, q}^i \leq 0, \quad j \in \mathcal{C}_{\text{cont}}, \end{aligned}$$

$$\begin{aligned}
& r_{j,q}^i - b_{j,q+1} + \boxed{M\alpha_{j,q}^i} \leq M - m_j, & \textcolor{blue}{j} \in \mathcal{C}_{\text{cont}}, \\
& r_{j,q}^i - b_{j,q+1} - \boxed{M\alpha_{j,q}^i} \geq -M - m_j, & \textcolor{blue}{j} \in \mathcal{C}_{\text{cont}}, \\
& \sum_{j \in \mathcal{C}_{\text{cont}}} \left[ \prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] \left[ \sum_{q=0}^{p_j} q\alpha_{j,q}^i \right] \\
& + \sum_{j \in \mathcal{C}_{\text{cat}}} \left[ \prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] v_{j,x_j^i} \\
& - \sum_{\beta=0}^{B-1} \beta \gamma_{\beta}^i = 0, \\
& \sum_{q=0}^{p_j} \alpha_{j,q}^i = 1, & j \in \mathcal{C}_{\text{cont}}, \\
& v_{j,x_j^i} + Mf_j \geq 0, & j \in \mathcal{C}_{\text{cat}}, \\
& v_{j,x_j^i} - Mf_j \leq 0, & j \in \mathcal{C}_{\text{cat}}, \\
& \sum_{(j,\tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} + \sum_{j \in \mathcal{C}_{\text{cat}}} f_j \leq d, \\
& \sum_{\beta=0}^{B-1} \gamma_{\beta}^i = 1, \\
& h_{\beta} + \sum_{i=1}^{\boxed{N}} y_k^i \gamma_{\beta}^i + N z_{\beta,k} \geq 0, \\
& \sum_{k=0}^n z_{\beta,k} = n, \\
& l_{j,q}^i, r_{j,q}^i, b_{j,q} \in \mathbb{R}, & j \in \mathcal{C}_{\text{cont}}, \\
& h_{\beta} \in \mathbb{R}, \\
& \textcolor{blue}{c}_{j,\tilde{j}} \in \{0, 1\}, & (j, \tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}, \\
& \alpha_{j,q}^i \in \{0, 1\}, & j \in \mathcal{C}_{\text{cont}}, \\
& f_j \in \{0, 1\}, & j \in \mathcal{C}_{\text{cat}}, \\
& v_{j,x_j^i} \in \{0, 1, \dots, p_j\}, & j \in \mathcal{C}_{\text{cat}}, \\
& \alpha_{j,q}^i, \gamma_{\beta}^i, z_{\beta,k} \in \{0, 1\}.
\end{aligned}$$

#### 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 also 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
<code>cplex.intsollim</code>	MIP solution number limit
<code>cplex.tilim</code>	Time limit per optimizer call (in seconds)
<code>cplex.threads</code>	Parallel threads (default: 0 implying up to 32 threads) <sup>14</sup>
<code>cplex.workmem</code>	Working memory before compression and swap (in MB) (default: 2048)
<code>cplex.trelim</code>	Uncompressed tree limit (in MB) (default: $10^{75}$ ) <sup>14</sup>
<code>cplex.nodefileind</code>	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
<code>cplex.status</code>	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  $c_{j,j}^* = 1$ . 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

```

1  /* **** */
2  * OPL 22.1.1.0 Model
3  * Author: songkomkrit
4  * Creation Date: Nov 4, 2024 at 12:24:05 AM
5  *****/
6

```

```

7  ****
8  * NOTES
9  * pl.bc.solutionValue[thisOplModel.mPairs.find(1,0)]
10 ****/
11
12 ****
13 * Class Labels
14 * Input file: 0, 1, 2, ..., n
15 * Algorithm: 0, 1, 2, ..., n
16 * Output file: 0, 1, 2, ..., n
17 ****/
18
19 ****
20 * INPUTS
21 ****/
22 int mdimold = 3; // dimension // 4 or 184 or 8 or 4
23 int mdimcontold = 1; // continuous dimension // 2 or 66 or 3 or 2
24 //int mdimcat = 2; // categorical dimension // 2 or 118 or 5 or 2
25 int mN = 100; // number of instances // 8 or 157681 or 100 or 100
26 int mn = 4; // the value of n = (number of classes) - 1 // 1 or 4 or 4
27
28 int mseltol = 2; // given number of total selected cont/cat dimensions (at
      most)
29
30 // Initialized UB on number of selected continuous dimensions
31 int mselcont = mdimcontold;
32 execute {
33   if (mselcont > mseltol)
34     mselcont = mseltol;
35 }
36
37 int mexcont = mdimcontold - mselcont; // computed LB on number of
      excluded continuous dimensions
38 int mdim = mdimold - mexcont;
39 int mdimcont = mselcont;
40

```

```

41 range mDS = 1..mdim;
42 range mDSCONTOLD = 1..mdimcontold; // old continuous
43 range mDSCONT = 1..mselcont; // new continuous
44 range mDSCAT = mdimcont+1..mdim; // shifted categorical
45 range mIS = 1..mN;
46 float mxcontold[mIS][mDSCONTOLD]; // x along continuous dimensions
47 int mxcat[mIS][mDSCAT]; // x along categorical dimensions
48 int my[mIS];
49 int mmaxlab[mDSCAT]; // maximum labels for categorical dimensions
50 float mM[mDS]; // big-M for all new/shifted dimensions (continuous and
categorical)
51 float mm[mDSCONT]; // small-m for continuous dimensions
52 int mp[mDS]; // number of cuts along axes
53 int mcoef[mDS];
54
55 ****
56 * TUPLES
57 ****
58 tuple ContPairType { // index for continuous cut
59     int j;
60     int q;
61 };
62
63 {ContPairType} mContPairs = {<j, q> | j in mDSCONT, q in 0..mp[j]+1};
64
65 tuple ContTripleType { // index for continuous cut of each individual
instance
66     int i;
67     int j;
68     int q;
69 };
70
71 {ContTripleType} mContTriples = {<i, j, q> | i in mIS, j in mDSCONT, q in
0..mp[j]};
72
73 tuple CatPairType { // index for categorical group

```

```

74     int j;
75     int l;
76 };
77
78 {CatPairType} mCatPairs = {<j, l> | j in mDSCAT, l in 0..mmaxlab[j]};
79
80 tuple tuplePred {
81     key int b;
82     sorted {int} label;
83 }
84 sorted {tuplePred} mpred;
85 {int} memptyset = {};
86
87 ****
88 * OUTSIDE EXECUTION
89 ****
90 execute {
91     thisOplModel.settings.run_engineLog = "tmp/current-engine.log"; //
92     temporary engine log
93 }
94 ****
95 * MAIN EXECUTION
96 ****
97 main {
98     var ftime = Opl.round((new Date()).getTime()/1000) % 100000; // first
99     timestamp (in seconds)
100
101    // Input/variable filenames
102    var infilename = "input/seltrain20num3each20.csv"; // input filename
103    var varfilename = "input/selproc20num3co3ca3cutinfo.csv"; // variable
104    filename (6 columns)
105
106    // Prefix of all output files
107    var prefixout = "output/" + ftime + "-";
108    prefixout += infilename.split("/")[1].split(".")[0] + "-";

```

```

107
108    // Inputs
109    //var M0 = 500;    // big-M (float)
110    var m0 = 0.01;   // small-m (float)
111    var pcont0 = 3;  // max number of cuts along continuous axis (integer)
112
113    // Customization
114    var timelimit = 1; // whether set total time limits (1 = limit / 0 =
115        none)
115    var limit = 1;    // whether customize performance settings (1 =
116        customize / 0 = none)
116    var perf = 1;     // whether set limits (1 = limit / 0 = none)
117
118    // Custom time limit parameter
119    if (timelimit == 1)
120        var acctimelimmin = 24*60; // accumulated time limit (in minutes)
121
122    // Cplex limit parameters (excluding time limit)
123    if (limit == 1) {
124        var intsollim = 1; // MIP solution number limit (in each iteration)
125    }
126
127    // Cplex performance parameters
128    if (perf == 1) {
129        var threads = 0; // parallel threads (default: 0 = at most 32
130            threads)
130        var workmemgb = 2; // working memory before compression and swap (
131            in GB) (default: 2 GB) (only marginally improved efficiency)
131        var treelimgb = 200; // uncompressed tree memory limit (in GB) (
132            default: around 1e+72 GB)
133
133    /* Node storage file switch
134        * 0 = No node file
135        * 1 = Node file in memory and compressed (default)
136        * 2 = Node file on disk
137        * 3 = Node file on disk and compressed

```

```

138      */
139      var nodefileind = 3;
140
141      /* Note on directory for temporary working files
142      * cplex.workdir = ...;
143      * CPLEX Error 1422: Could not open file for writing
144      */
145
146      // Calculation
147      var workmem = 1024*workmemgb; // 14 working memory before compression
148      and swap (in MB) (default: 2048 MB)
149      var trelim = 1024*trelimgb; // uncompressed tree memory limit (in
150      MB) (default: 1e+75 MB)
151  }
152
153  // Postfixes
154  var cpostfixname = "mfullaltseltol-" + thisOplModel.mseltol; // common
155  postfix name
156  if (timelimit == 1)
157      cpostfixname += "-t-" + acctimelimmin + ".csv";
158  else
159      cpostfixname += ".csv";
160  var postfixerror = "-" + cpostfixname; // postfix of error file
161  var postfixout = "-pcont-" + pcont0 + "-" + cpostfixname; // postfix of
162  all other output files
163
164  // Output filenames
165  var outerrorname = prefixout + "export-error" + postfixerror;
166  var outinstancename = prefixout + "export-predict-instance" +
167      postfixout;
168  var outcutconname = prefixout + "export-cutcont-full" + postfixout;
169  var outcutcatname = prefixout + "export-cutcat-full" + postfixout;
170
171  // The existence of region is not checked here
172  // In fact, it can be check through enumeration of certain binary
173  representations
174  var outregionname = prefixout + "export-predict-region" + postfixout;

```

```

168     var outselvarintname = prefixout + "export-select-var-int" + postfixout
169         ; // selected variables (integer)
170
171     var outselvarstrname = prefixout + "export-select-var-str" + postfixout
172         ; // selected variables (string)
173
174     // Engine log (initialized)
175
176     var logfilename = "log/" + ftime + "-engine-" + cpostfixname.split(".")
177         [0] + ".log";
178
179     var outlog = new IloOplOutputFile(logfilename);
180
181     // OPL
182
183     var source = new IloOplModelSource("p-mixed-cuts-alt-seltol.mod");24
184
185     var cplex = new IloCplex();
186
187     var def = new IloOplModelDefinition(source);
188
189     var opl = new IloOplModel(def,cplex);
190
191     var data = new IloOplDataElements();
192
193     data.dimold = thisOplModel.mdimold;
194
195     data.dimcontold = thisOplModel.mdimcontold;
196
197     data.dim = thisOplModel.mdim;
198
199     data.dimcont = thisOplModel.mdimcont;
200
201     //data.dimcat = thisOplModel.mdimcat;
202
203     data.N = thisOplModel.mN;
204
205     data.n = thisOplModel.mn;
206
207     data.xcontold = thisOplModel.mxcontold;
208
209     data.xcat = thisOplModel.mxcat;
210
211     data.y = thisOplModel.my;
212
213
214     var pred = thisOplModel.mpred; // set of predicted labels
215
216
217     data.seltol = thisOplModel.mseltol;
218
219     data.selcont = thisOplModel.mselcont;
220
221     data.excccont = thisOplModel.mexcccont;
222
223
224     data.m = thisOplModel.mm;
225
226     for (var j=1; j<=data.dimcont; j++)

```

```

201     data.m[j] = m0;
202
203     var f = new IloOplInputFile(infilename); // training dataset
204     f.readline();           // skip a header
205     for (var i=1; i<=data.N; i++) {
206         var myitem = f.readline().split(",");
207         data.y[i] = Opl.intValue(myitem[data.dimold]);
208         for (var j=1; j<=data.dimcontold; j++)
209             data.xcontold[i][j] = Opl.floatValue(myitem[j-1]);
210         for (var j=data.dimcontold+1; j<=data.dimold; j++)
211             data.xcat[i][j-data.exccont] = Opl.intValue(myitem[j-1]);
212     }
213     f.close();
214
215     data.p = thisOplModel.mp;
216     for (var j=1; j<=data.dimcont; j++)
217         data.p[j] = pcont0;
218
219     data.M = thisOplModel.mM;
220     data.maxlab = thisOplModel.mmaxlab;
221     var M0cont = 1;
222     var f = new IloOplInputFile(varfilename); // variable info
223     f.readline();           // skip a header
224     for (var j=1; j<=data.dimold; j++) {
225         var myitem = f.readline().split(",");
226         if (j <= data.dimcontold) {
227             var curMcont = 1 + Opl.maxl(Opl.abs(Opl.intValue(myitem[3])),
228                                         Opl.abs(Opl.intValue(myitem[4])));
229             M0cont = Opl.maxl(M0cont, curMcont);
230         }
231         else {
232             data.p[j-data.exccont] = Opl.intValue(myitem[5]);
233             data.maxlab[j-data.exccont] = Opl.intValue(myitem[4]);
234             data.M[j-data.exccont] = 1 + Opl.intValue(myitem[5]);
235         }
236     }

```

```

236     f.close();
237
238     for (var j=1; j<=data.dimcont; j++)
239         data.M[j] = M0cont;
240
241     data.coef = thisOplModel.mcoef;
242     data.coef[1] = 1;
243     for (var j=2; j<=data.dim; j++)
244         data.coef[j] = data.coef[j-1]*(data.p[j]+1);
245
246     var nump = 0; // total number of cuts
247     for (var j=1; j<=data.dim; j++)
248         nump += data.p[j];
249
250     97
251     opl.addDataSource(data);
252     opl.generate();
253     opl.settings.mainEndEnabled = true;
254
255     // Cplex limits (excluding time limit)
256     if (limit == 1) {
257         cplex.intsollim = intsollim; // MIP solution number limit (> 0)
258     }
259
260     // Cplex performance
261     if (perf == 1) {
262         cplex.threads = threads; // parallel threads
263         cplex.workmem = workmem; // working memory before compression and
264         swap (in MB)
265         cplex.trelim = trelim; // uncompressed tree memory limit (in MB)
266         cplex.nodefileind = nodefileind; // node storage file switch
267     }
268
269     // Initialization
270     var status = -9; // solution status code (initialized)
271     var iter = 0; // iteration
272     var acctime = 0; // accumulated running time (in seconds)

```

```
271     var texceed = 0; // whether acctime > tilimmin (1 = total time limit
272         exceeded / 0 = not)
273
274     // Calculation
275     if (timelimit == 1)
276         var acctimelim = 60*acctimelimmin; // accumulated time limit (in
277             seconds)
278     else
279         var acctimelim = -1;
280
281     // Optimization
282     while (texceed == 0) { // accumulated time limit not exceeded
283
284         // Exit status codes
285         if (status == 1) // 1: CPX_STAT_OPTIMAL
286             break;
287         else if (status == 101) // 101: CPXMIP_OPTIMAL
288             break;
289         else if (status == 102) // 102: CPXMIP_OPTIMAL_TOL
290             break;
291         else if (status == 111) // 111: CPXMIP_MEM_LIM_FEAS
292             break;
293         else if (status == 112) // 112: CPXMIP_MEM_LIM_INFEAS
294             break;
295
296         /* Non-exit status codes
297          * 11: CPX_STAT_ABORT_TIME_LIM
298          * 104: CPXMIP_SOL_LIM
299          */
300
301         // In the case when the previous status is not one of the above
302         if (timelimit == 1) // time limit for each call to optimizer (in
303             seconds)
304             cplex.tilim = acctimelim - acctime;
305         var start = new Date(); // begin a timer
306
```

```

304     pred.clear(); // clear previous set of predicted labels
305
306     // Solve
307     if (cplex.solve()) {
308
309         var end = new Date(); // end a timer
310         var solvetime = end.getTime() - start.getTime(); // compute
311             solving time
312         acctime += solvetime/1000; // accumulated running time (in s)
313
314         if ((timelimit == 1) && (acctime >= acctimelim)) // total time
315             limit exceeded (in seconds)
316         texceed = 1;
317
318         iter += 1; // update iteration
319
320         var error = data.N + cplex.getObjValue(); // the number of
321             misclassified instances
322         var accuracy = (1-error/data.N)*100; // training accuracy
323
324         status = cplex.status; // solution status code (1 = opt / 11 =
325             time limit / ...)
326         var lberr = data.N + cplex.getBestObjValue(); // LB on minimum
327             (optimal) error
328         var relgap = cplex.getMIPRelativeGap(); // relative objective
329             gap for MIP
330
331         // Open output text files (append = true)
332         var outerror = new IloOplOutputFile(outerrorname, true);
333         var outinstance = new IloOplOutputFile(outinstancename, true);
334         var outcutcont = new IloOplOutputFile(outcutcontname, true);
335         var outcutcat = new IloOplOutputFile(outcutcatname, true);
336         var outregion = new IloOplOutputFile(outregionname, true);
337         var outselvarint = new IloOplOutputFile(outselvarintname, true);

```

```

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

333
334         // outerror
335         if (!outerror.exists) {
336             outerror.write("iter,");
337             for (var j=1; j<=data.dim; j++)
338                 outerror.write("p", j, ",");
339                 outerror.write("error,accuracy,ms,acctmin,status,lberr,
340                               relgap");
341             }
342             outerror.write("\n", iter, ",");
343             for (var j=1; j<=data.dim; j++)
344                 outerror.write(data.p[j], ",");
345                 outerror.write(error, "", accuracy, ",");
346                 outerror.write(solvetime, "", acctime/60, ",");
347                 outerror.write(status, "", lberr, "", relgap);

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

360
361         // Create a set of predicted labels (majority voting)
362         for (var b=0; b<opl.B; b++) {
363             var lset = Opl.operatorUNION(thisOplModel.memptyset,
364                                         thisOplModel.memptyset);
365             var maxnum = 0;

```

```

365         for (var k=0; k<=data.n; k++) {
366             var num = 0;
367             for (var i=1; i<=data.N; i++)
368                 num += (data.y[i] == k)*opl.g.solutionValue[i][b];
369
370                 if (num == maxnum)
371                     lset.add(k);
372                 else if (num > maxnum) {
373                     maxnum = num;
374                     lset.clear();
375                     lset.add(k);
376                 }
377             pred.add(b, lset);
378         }
379
380         // outinstance
381         if (!outinstance.exists)
382             outinstance.write("iter,id,class,region,predict");
383             for (var i=1; i<=data.N; i++) {
384                 outinstance.write("\n", iter, "", i, "", data.y[i], "");
385                 for (var b=0; b<opl.B; b++)
386                     if (opl.g.solutionValue[i][b] == 1) { // occur only once
387                         outinstance.write(b, ",");
388                         outinstance.write(pred.get(b).label);
389                         break; // terminate the loop
390                     }
391             }
392
393         // outcutcont
394         if (!outcutcont.exists)
395             outcutcont.write("iter,j,q,bc");
396             for (var j=1; j<=data.dimcont; j++) {
397                 for (var q=1; q<=data.p[j]; q++) {
398                     outcutcont.write("\n", iter, "", j, "", q, ",");

```

```

399         outcutcont.write(opl.bc.solutionValue[thisOplModel.
400             mContPairs.find(j,q)]);
401     }
402 }
403 // outcutcat
404 if (!outcutcat.exists)
405     outcutcat.write("iter,j,l,v");
406 for (var j=data.dimcont+1; j<=data.dim; j++) {
407     for (var l=0; l<=data.maxlab[j]; l++) {
408         outcutcat.write("\n", iter, ", ", j, ", ", l, ", ");
409         outcutcat.write(opl.v.solutionValue[thisOplModel.
410             mCatPairs.find(j,l)]);
411     }
412 }
413 // outregion
414 if (!outregion.exists)
415     outregion.write("iter,region,occupy,predict");
416 for (var b=0; b<opl.B; b++) {
417     outregion.write("\n", iter, ", ", b, ", ");
418     var s = 0; // initialize s (presumably unoccupied)
419     for (var i=1; i<=data.N; i++)
420         if (opl.g.solutionValue[i][b] == 1) { // occupied
421             s = 1;
422             break; // iterminate the loop
423         }
424     outregion.write(s, ",");
425     outregion.write(pred.get(b).label);
426 }
427 // outselvarint
428 if (!outselvarint.exists)
429     outselvarint.write("iter,j,jold,mselect,type"); // mselect =
430         model select (not actual)

```

```

431     for (var j=1; j<=data.dimcont; j++) { // selected continuous
432         features
433         outselvarint.write("\n", iter, ",", j, ",");
434         var seljold = -1;
435         for (var jold=1; jold<=data.dimcontold; jold++)
436             // Determine which old continuous feature is selected
437             if (opl.ccont.solutionValue[j][jold] == 1) {
438                 seljold = jold;
439                 break; // terminate the loop
440             }
441         outselvarint.write(seljold, ",");
442         outselvarint.write("1,"); // Based on model, all new cont
443         features are selected
444         outselvarint.write("cont");
445     }
446     for (var j=data.dimcont+1; j<=data.dim; j++) { // categorical
447         feature
448         outselvarint.write("\n", iter, ",", j, ",", j+data.exccont,
449             ",");
450         if (opl.f.solutionValue[j] == 1) // selected categorical
451             feature (model)
452             outselvarint.write("1,");
453             else // unselected categorical feature (model)
454                 outselvarint.write("0,");
455             outselvarint.write("cat");
456     }
457     // outselvarstr
458     if (!outselvarstr.exists)
459         outselvarstr.write("iter,jold,jnew,aselect,type,variable");
460         // aselect = actual select
461     var varinfilename = new IloOplInputFile(varfilename); // variable
462         info
463     varinfilename.readline(); // skip a header
464     var numselcont = 0; // initialized number of actually selected
465         continuous features

```

```

459     var numselcat = 0; // initialized number of actually selected
        categorical features
460     for (var jold=1; jold<=data.dimcontold; jold++) { // CONTINUOUS
461         outselvarstr.write("\n", iter, ",", jold, ",");
462         var jnew = -1;
463         var aselect = 0; // initialized to be unselected (continuous
464             )
465         for (var j=1; j<=data.dimcont; j++)
466             // Determine whether a current old continuous feature is
467             selected
468             if (opl.ccont.solutionValue[j][jold] == 1) { // selected
469                 (actual 1/2)
470                 jnew = j;
471                 break; // terminate the loop
472             }
473             outselvarstr.write(jnew, ",");
474             var myitem = varinfile.readline().split(",");
475             if (jnew > 0) { // selected continuous feature (actual 1/2)
476                 aselect = 1; // seem to be selected (initialization for
477                 actual 2/2)
478                 for (var q=0; q<=data.p[jnew]; q++) {
479                     var bcleft = opl.bc.solutionValue[thisOplModel.
480                         mContPairs.find(jnew,q)];
481                     var bcright = opl.bc.solutionValue[thisOplModel.
482                         mContPairs.find(jnew,q+1)];
483                     var minxjnew = Opl.intValue(myitem[3]);
484                     var maxxjnew = Opl.intValue(myitem[4]);
485                     if ((bcleft <= minxjnew) && (bcright >= maxxjnew)) {
486                         // cover [min,max]
487                         aselect = 0; // unselected (actual 2/2)
488                         break;
489                     }
490                 }
491             }
492             outselvarstr.write(aselect, ",");
493             if (aselect == 1) { // actually selected continuous feature

```

```

487         // Scripting logs 2 (continuous)
488         write("\t", myitem[1], " (Continuous)\n");
489         numselcont += 1;
490     }
491     outselvarstr.write("cont,");
492     outselvarstr.write(myitem[1]); // variable name
493 }
494 for (var jold=data.dimcontold+1; jold<=data.dimold; jold++) { //
495     CATEGORICAL
496     var jnew = jold-data.exccont;
497     outselvarstr.write("\n", iter, ", ", jold, ", ", jnew, ",");
498     var aselect = 0; // initialized to be unselected (
499         categorical)
500     var myitem = varinfile.readline().split(",");
501     if (opl.f.solutionValue[jnew] == 1) { // selected
502         categorical feature (actual 1/2)
503         var vat0 = opl.v.solutionValue[thisOplModel.mCatPairs.
504             find(jnew,0)];
505         for (var l=1; l<=data.maxlab[jnew]; l++) {
506             var vcur = opl.v.solutionValue[thisOplModel.mCatPairs
507                 .find(jnew,l)];
508             if (vcur != vat0) { // distinct new groups are
509                 detected
510                 aselect = 1; // selected categorical feature (
511                     actual 2/2)
512                 break;
513             }
514         }
515         outselvarstr.write(aselect, ",");
516         if (aselect == 1) { // actually selected categorical feature
517             // Scripting logs 2 (categorical)
518             write("\t", myitem[1], " (Categorical)\n");
519             numselcat += 1;
520         }
521         outselvarstr.write("cat,");

```

```

516         outselvarstr.write(myitem[1]);
517     }
518     varinfile.close();
519
520     // Scripting logs 3
521     var numselall = numselcont + numselcat;
522     writeln("\nNumber of selected variables = ", numselall, " (",
523           numselcont, " continuous + ", numselcat, " categorical)");
524     writeln("-----");
525
526     // Closing output text files
527     outerror.close();
528     outinstance.close();
529     outcutcont.close();
530     outcutcat.close();
531     outregion.close();
532     outselvarint.close();
533     outselvarstr.close();
534
535     24
536     else
537
538     opl.end();
539     data.end();
540     def.end();
541     cplex.end();
542     source.end();
543
544     // Engine log (exported)
545     var inlog = new IloOplInputFile("tmp/current-engine.log");
546     while (!inlog.eof) {
547         outlog.writeln(inlog.readline());
548     }
549     inlog.close();
550     outlog.close();

```

551 }

Code 4.2: Box classifier OPL model

```

1  ****
2   * OPL 22.1.1.0 Model
3   * Author: songkomkrit
4   * Creation Date: Nov 4, 2024 at 1:15:57 AM
5  ****
6
7  ****
8  * DATA INFORMATION (INPUTS)
9  ****
10 int dimold = ...; // old dimension
11 int dimcontold = ...; // old continuous dimension
12 int dim = ...; // new dimension
13 int dimcont = ...; // new continuous dimension
14 //int dimcat = ...; // categorical dimension
15 int N = ...; // number of instances
16 int n = ...; // number of classes
17
18 ****
19 * FEATURE SELECTION (INPUTS)
20 ****
21 int seltol = ...; // given number of total selected cont/cat dimensions (
    at most)
22 int selcont = ...; // UB on number of selected continuous dimensions
23 int exccont = ...; // computed LB on number of excluded continuous
    dimensions
24
25 ****
26 * INDEX RANGES 1
27 ****
28 range DS = 1..dim; // for dimensions
29 range DSCONTOLD = 1..dimcontold; // for old continuous dimensions

```

```

30 range DSCONT = 1..dimcont; // for new continuous dimensions
31 range DSCAT = dimcont+1..dim; // for shifted categorical dimensions
32 range IS = 1..N; // for instances
33 range KS = 0..n; // for classes
34
35 ****
36 * INITIAL PARAMETERS (INPUTS)
37 ****
38 float M[DS] = ...; // big-M for all new/shifted dimensions (continuous
and categorical)
39 float m[DSCONT] = ...; // small-m for new continuous dimensions
40
41 ****
42 * DATA EXTRACTION (INPUTS)
43 ****
44 float xcontold[IS][DSCONTOLD] = ...; // instances along old continuous
dimensions
45 int xcat[IS][DSCAT] = ...; // instances along shifted categorical
dimensions
46 int y[IS] = ...; // targets
47 int maxlab[DSCAT] = ...; // maximum labels for new categorical dimensions
48 int p[DS] = ...; // number of cuts along axes
49 int coef[DS] = ...; // product coefficients
50
51 ****
52 * NUMBER OF BOXES
53 ****
54 int B = 1; // initialize the number of boxes
55 execute {
56   for (var j in DS)
57     B = B*(p[j]+1); // compute the number of boxes
58 }
59
60 ****
61 * INDEX RANGES 2
62 ****

```

```

63 range BS = 0..B-1; // for regions
64
65 *****
66 * TUPLES
67 *****
68 tuple ContPairType { // index for continuous cut
69     int j;
70     int q;
71 };
72
73 {ContPairType} ContPairs = {<j, q> | j in DSCONT, q in 0..p[j]+1};
74
75 tuple ContTripleType { // index for continuous cut of each individual
76     instance
77     int i;
78     int j;
79     int q;
80 };
81 {ContTripleType} ContTriples = {<i, j, q> | i in IS, j in DSCONT, q in 0..
82     p[j]};
83
84 tuple CatPairType { // index for categorical group
85     int j;
86     int l;
87 };
88 {CatPairType} CatPairs = {<j, l> | j in DSCAT, l in 0..maxlab[j]};
89
90 *****
91 * DECISION VARIABLES
92 *****
93 dvar float l[ContTriples];
94 dvar float r[ContTriples];
95 dvar float bc[ContPairs]; // bc is in R (c = cut)
96 // Note that b is used for beta indexing

```

```

97 dvar float h[BS]; // h
98 dvar boolean a[ContTriples]; // alpha
99 dvar int+ v[CatPairs]; // v (categorical features)
100 dvar boolean g[IS][BS]; // gamma
101 dvar boolean z[BS][KS]; //
102 // Feature selection
103 dvar boolean ccont[DSCONT][DSCONTOLD]; // select continuous dimensions
104 dvar boolean f[DSCAT]; // select categorical dimensions
105
106 ****
107 * OBJECTIVE FUNCTION
108 ****
109 minimize sum(b in BS) h[b]; // min total number of misclassified
    instances
110
111 ****
112 * CONSTRAINTS
113 ****
24 114 subject to {
115
116     forall(j in DSCONT)
117         getnewcont:
118             sum(jold in DSCONTOLD) ccont[j][jold] <= 1;
119
120     forall(jold in DSCONTOLD)
121         seloldcont:
122             sum(j in DSCONT) ccont[j][jold] <= 1;
123
124     forall(j in DSCONT, q in 0..p[j])
125         bc[<j,q+1>] - bc[<j,q>] >= 0;
126
127     forall(i in IS, j in DSCONT) {
128         lbound:
129             (sum(jold in DSCONTOLD) xcontold[i][jold]*ccont[j][jold]) - (
130                 sum(q in 0..p[j]) l[<i,j,q>]) >= 0;
131         rbound:

```

```

131         (sum(jold in DSCONTOLD) xcontold[i][jold]*ccont[j][jold]) - (
132             sum(q in 0..p[j]) r[<i,j,q>] <= 0;
133
134     forall(i in IS, j in DSCONT, q in 0..p[j]) {
135         41 1[<i,j,q>] + M[j]*a[<i,j,q>] >= 0;
136         1[<i,j,q>] - M[j]*a[<i,j,q>] <= 0;
137         1[<i,j,q>] - bc[<j,q>] + M[j]*a[<i,j,q>] 10 <= M[j] + m[j];
138         81 1[<i,j,q>] - bc[<j,q>] - M[j]*a[<i,j,q>] >= -M[j] + m[j];
139         41 r[<i,j,q>] + M[j]*a[<i,j,q>] >= 0;
140         r[<i,j,q>] - M[j]*a[<i,j,q>] <= 0;
141         r[<i,j,q>] - bc[<j,q+1>] + M[j]*a[<i,j,q>] 10 <= M[j] - m[j];
142         r[<i,j,q>] - bc[<j,q+1>] - M[j]*a[<i,j,q>] >= -M[j] - m[j];
143     }
144
145     62 forall(i in IS)
146         (sum(j in DSCONT) coef[j]*(sum(q in 0..p[j]) q*a[<i,j,q>])) + (sum(
147             j in DSCAT) coef[j]*v[<j,xcat[i][j]>]) - (sum(b in BS) b*g[i][b]
148             ]) == 0;
149
150     forall(i in IS, j in DSCONT)
151         pregion:
152             sum(q in 0..p[j]) a[<i,j,q>] == 1;
153
154     forall(i in IS) {
155         bregion:
156             sum(b in BS) g[i][b] == 1;
157
158         forall(b in BS, k in KS)
159             error1:
160                 h[b] + (sum(i in IS) (y[i] == k)*g[i][b]) + N*z[b][k] >= 0;
161
162         forall(b in BS)
163             error2:
164                 sum(k in KS) z[b][k] == n;

```

```

164
165     forall(j in DSCAT, l in 0..maxlab[j])
166         v[<j,l>] <= p[j];
167
168     forall(i in IS, j in DSCAT) {
169         selcat1:
170             84 v[<j,xcat[i][j]>] + M[j]*f[j] >= 0;
171         selcat2:
172             84 v[<j,xcat[i][j]>] - M[j]*f[j] <= 0;
173     }
174
175     seltolnum:
176         (sum(j in DSCONT, jold in DSCONTOLD) ccont[j][jold]) + (sum(j in
177             DSCAT) f[j]) <= seltol;
177 }
```

#### 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 ( $c_{j,j}^* = 0$ ), 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  $v_{j,x_j}^*$  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.

<sup>56</sup> Suppose only  $d'$  out of  $d$  features are finally selected. The feature map  $\sigma : \{0, 1, \dots, d\} \rightarrow \{-1\} \cup \{0, 1, \dots, d'\}$  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  $\sigma$  includes  $0, 1, \dots, d'$ . 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  $\beta$  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:

$$\text{(122)} \quad g(\beta) - g(\beta - 1) = - \sum_{j=1}^{w-1} p_j \prod_{j' \in \Sigma_j} (p_{j'} + 1) + 1 \cdot \prod_{j' \in \Sigma_w} (p_{j'} + 1)$$

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)

```
1 import os
```

```
2 import shutil
3 import json
4 import math
5 import numpy as np
6 import pandas as pd
7
8 # Create directory (if not exist)
9 def create_dir(dir):
10     ...
11     Usage: create directory (if not exist)
12     Required arguments:
13         dir: directory name
14     ...
15
16     try: os.makedirs(dir)
17     except FileExistsError: pass
18
19
20 # Copy single file
21 def copy(srcpath, destpath):
22     ...
23     Usage: copy single file
24     Required arguments:
25         srcpath: source pathname
26         destpath: destination pathname
27     ...
28
29     # Split path into directory and file
30     srcdir, srcfile = os.path.split(srcpath) # source
31     destdir, destfile = os.path.split(destpath) # destination
32
33     # Create destination directory (if not exist)
34     create_dir(destdir)
35
36     # Copy source file into destination folder (filename unchanged)
37     shutil.copy2(srcpath, destdir) # preserve file metadata
```

```
38
39     # Rename copied file to correct destination filename
40     os.rename(f"{destdir}/{srcfile}", destpath)
41
42
43 # Round up or down number to decimal places
44 def round_num(number, decimals, direction):
45     """
46         Usage: round up or down number to decimal places
47         Required arguments:
48             number: number to be rounded
49             decimals: number of decimal places to round to
50             direction: either up or down ('up', 'down')
51         Outputs:
52             rounded number to specified decimal places
53     """
54
55     if isinstance(decimals, int) or isinstance(decimals, np.integer):
56         if decimals >= 0:
57             if direction == 'up':
58                 return math.ceil(number*10**decimals)/10**decimals
59             elif direction == 'down':
60                 return math.floor(number*10**decimals)/10**decimals
61             else:
62                 raise TypeError("Direction can be either up or down")
63         else:
64             raise TypeError("Number of decimal places to round to must be
65                             nonnegative")
66     else:
67         raise TypeError("Number of decimal places must be an integer")
68
69 # Find maximum value of dictionary and key set
70 def max_dictval(dc):
71     """
```

```

72     Usage: find maximum value of dictionary and all of its
73         corresponding keys
74     Required arguments:
75         dc: dictionary
76     Outputs:
77         kmax: set of all keys of maximum value
78         vmax: maximum value
79     ...
80
81     kmax = set()
82     vmax = dc[next(iter(dc))] # value of first key
83     for k, v in dc.items():
84         if v > vmax:
85             vmax = v
86             kmax = {k}
87         elif v == vmax:
88             kmax.add(k)
89
90
91
92 # Find interval index of specific value from list of real-line splits
93 def itvpos(x, splits, closed='neither'):
94     ...
95     Usage: find interval index of specific value from array of real-
96         line splits
97     Required arguments:
98         x: specific value of interest
99         splits: list of real line splits
100        closed: whether intervals are closed on left-side, right-side
101        or neither ('left', 'right', 'neither')
102     Outputs:
103         interval index of specific input value
104
105        ...
106
107        if closed == 'left': # [_, s), [s, _)

```

```

105     for i, s in enumerate(splits):
106         if x < s: return i
107     elif closed == 'neither': # (_, s), (s, _)
108         for s in splits:
109             if x == s:
110                 raise Exception(f"Open intervals are chosen but input value
111 {x} is at split value {s}")
112             closed = 'right' # now safe to be extended to (_, s], (s, _]
113     if closed == 'right': # (_, s], (s, _]
114         for i, s in enumerate(splits):
115             if x <= s:
116                 return i
117
118     # Last interval
119     return i + 1
120
121
122 # Return left and right endpoints of rounded interval
123 def itvopts(itv, decimals=2, extend=True):
124     """
125         Usage: return left and right endpoints of rounded interval
126         Required arguments:
127             itv: Pandas interval to be rounded
128         Optional arguments:
129             36decimals: number of decimal places to round to (default: 2)
130             extend: whether extend (true) or shrink (default) interval (
131                 default: True)
132         Outputs:
133             lpt: left endpoint of rounded interval
134             rpt: right endpoint of rounded interval
135
136     if isinstance(itv, pd._libs.interval.Interval):
137         if extend:
138             ldirect, rdirect = 'down', 'up'

```

```
139     else:
140         ldirect, rdirect = 'up', 'down'
141
142     if np.isinf(itv.left):
143         lpt = itv.left
144     else:
145         lpt = round_num(itv.left, decimals, ldirect)
146
147     if np.isinf(itv.right):
148         rpt = itv.right
149     else:
150         rpt = round_num(itv.right, decimals, rdirect)
151
152     return lpt, rpt
153
154 else:
155     raise TypeError("Only Pandas intervals are allowed")
156
157
158 # Import dictionary from JSON file
159 def import_dict(jsonPath):
160     """
161         Usage: parse JSON data into dictionary
162         Required arguments:
163             jsonpath: JSON filepath (usually metadata filepath)
164         Outputs:
165             dictionary
166     """
167
168     with open(jsonPath) as file:
169         contents = file.read()
170
171     # JSON data is parsed into dictionary
172     return json.loads(contents)
173
174
```

```

175 # Export dataframe with nonduplicate entries
176 def nondup(df, ndcols, intcols=list(), intdtype='Int16'):
177     """
178         Usage: export dataframe with nonduplicate entries
179         Required arguments:
180             df: dataframe
181             ndcols: two-dimensional multilevel column lists with
182                 nonduplicate entries
183         Optional arguments:
184             intcols: integer columns (default: empty list)
185             intdtype: Pandas integer data type (default: 'Int16' or pd.
186                         Int16Dtype())
187             Outputs: same dataframe but without duplicate entries
188             ...
189             dfn = df.copy(deep=True)
190             for i in range(len(ndcols),0,-1): # iterate over multilevel column
191                 lists with nonduplicate entries
192                 ccols = [f for cols in ndcols[0:i] for f in cols]
193                 dfn.loc[dfn[ccols].duplicated(), ccols] = pd.NA
194             for col in intcols:
195                 dfn[col] = pd.array(dfn[col], dtype=intdtype)
196
197             return dfn

```

Code 4.4: Typecasting (module/operation/typecast.py)<sup>38</sup>

```

1 import numpy as np
2 import pandas as pd
3
4 from module.operation.xutil import itvtopts
5
6
7 # Convert set/number in string format to Python set
8 def strtoset(setstr):

```

```
9      """
10     Usage: convert set/number in string format to Python set
11     Required arguments:
12         setstr: set/number in string format
13     Outputs: corresponding set
14     """
15
16     strset = set(setstr.strip().strip('{}'))
17     try: strset.remove(' ') # for set of more than two elements
18     except: pass
19     numset = set(map(int, strset))
20
21     return numset
22
23
24 # Convert set to string
25 def settostr(st, sep=',', left='{', right='}'):
26     """
27     Usage: convert set to string
28     Required arguments:
29         st: set
30     Optional arguments:
31         sep: separator (default: ',')
32         left: left symbol (default: '{')
33         right: right symbol (default: '}')
34     Outputs: string representing given set
35     """
36
37     stre = sep.join([str(e) for e in st])
38
39     return f"{left}{stre}{right}"
40
41
42 # Convert Pandas interval to string
43 def itvtostr(itv, decimals=2, extend=True):
44     """
```

```

45     Usage: convert Pandas interval to string
46
47     Required arguments:
48         itv: Pandas interval
49
50     Optional arguments:
51         36 decimals: number of decimal places to round to (default: 2)
52         extend: whether extend (true) or shrink (default) interval (
53             default: True)
54
55     Outputs: string interval
56
57     ...
58
59     lpt, rpt = itvtopts(itv, decimals, extend)
60     l = f"{lpt:.{decimals}f}"
61     r = f"{rpt:.{decimals}f}"
62
63
64 # Describe Pandas interval in text format
65 def itvtodesc(itv, decimals=2, extend=True):
66     ...
67
68     Usage: describe Pandas interval in text format
69
70     Required arguments:
71         itv: Pandas interval
72
73     Optional arguments:
74         36 decimals: number of decimal places to round to (default: 2)
75         extend: whether extend (true) or shrink (default) interval (
76             default: True)
77
78     Outputs: description of interval in text format
79
80     ...
81
82
83     lpt, rpt = itvtopts(itv, decimals, extend)
84     l = f"{lpt:.{decimals}f}"
85     r = f"{rpt:.{decimals}f}"

```

```

79
80     esum = itv.left + itv.right
81     if np.isnan(esum): # -np.inf, np.inf
82         return "any number"
83     elif not np.isinf(esum): # num, num
84         return f"between {l} and {r}"
85     elif esum < 0: # -np.inf, num
86         return f"below {r}"
87     else: # num, np.inf
88         return f"above {l}"

```

Code 4.5: Recalculation of regions (module/operation/calregs.py)

```

1 import numpy as np
2
3
4 # Calculate new corresponding region label (helper)
5 def hcalbn(bo, bnpred, idxn, pcuto, pocum, pncumx):
6     """
7         Usage: calculate new corresponding region label (helper)
8         Required arguments:
9             bo: region label for old features (nonzero)
10            bnpred: previous region label for new features
11            idxn: new feature indexes
12            pcuto: old cut numbers
13            pocum: cumulative number of box regions across old features
14            pncumx: cumulative number of extended box regions across new
15                features
16            Outputs: corresponding region label
17        """
18    # bo must be between 1 and np.prod(pcuto+1)-1
19    bn = bnpred
20    for jmax in range(len(pcuto)-1,-1,-1):

```

```

21     # bo (incremented by 1) in base representation has the last nonzero
22     # at digit jmax
23     if bo%pocum[jmax] == 0:
24         for j in range(jmax):
25             bn -= pculo[j]*pncumx[idxn[j]]
26             bn += pncumx[idxn[jmax]]
27             break
28
29
30
31 # Calculate corresponding decision regions (helper)
32 def hcalregs(B0, idxn, pculo, pocum, pncumx):
33     ...
34     Usage: calculate corresponding decision regions (helper)
35     Required arguments:
36         B0: total number of old box regions
37         idxn: new feature indexes
38         pculo: old cut numbers
39         pocum: cumulative number of box regions across old features
40         pncumx: cumulative number of extended box regions across new
41         features
42     Outputs: corresponding region label
43     ...
44     bns = [0] # list of corresponding box regions (region 0)
45     for bo in range(1, B0):
46         bnperv = bns[-1]
47         bn = hcalbn(bo, bnperv, idxn, pculo, pocum, pncumx)
48         bns.append(bn)
49
50     return bns
51
52
53 # Calculate new corresponding decision regions (main)

```

```

54 def calregs(pculo, sidx, pdtype=np.int16, idtype=np.int16, rdtype=np.int16
55 ):
56     """
57     Usage: calculate new corresponding decision regions (main)
58     Required arguments:
59         pculo: old cut numbers
60         sidx: selected feature indexes (in order)
61     Optional arguments:
62         pdtype: NumPy data type of cut number (default: np.int16)
63         idtype: NumPy data type of index (default: np.int16)
64         rdtype: NumPy data type of region number (default: np.int16)
65     Outputs: new corresponding regions
66     """
67
68     # Typecasting
69     pculo = np.array(pculo, dtype=pdtype)
70     sidx = np.array(sidx, dtype=idtype)
71
72     # Basic calculation
73     dimo = pculo.size # old dimension
74     dimn = sidx.size # new dimension
75     pcutn = pculo[sidx] # new cut numbers
76     BO = np.prod(pculo+1).astype(rdtype) # number of old regions
77     BN = np.prod(pcutn+1).astype(rdtype) # number of new regions
78
79     # New feature indexes
80     idxn = np.full(dimo, -1, dtype=idtype)
81     idxn[sidx] = np.arange(dimn, dtype=idtype)
82     idxn[idxn < 0] = np.arange(dimn, dimo, dtype=idtype)
83
84     # Cumulative number of box regions
85     pocum = np.cumprod(np.append([1], pculo[0:-1]+1), dtype=rdtype) # old
86     pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=rdtype) # new
87     pncumx = np.concatenate((pncum, np.zeros(dimo-dimn, dtype=rdtype))) #
88     # new and extended

```

```

88     # New corresponding regions (helper function called)
89     bns = np.array(hcalregs(B0, idxn, pculo, pncumx), dtype=rdtype)
90
91     # Output
92     return bns
93
94
95 # Illustration
96 ***
97 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0],
98       calregs(pcuto, sidx)))
99 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1],
100      calregs(pcuto, sidx)))
101 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0,
102       1], calregs(pcuto, sidx)))
103 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1,
104       0], calregs(pcuto, sidx)))
105 ***

```

Code 4.6: Feature selection (module/model/findsels.py)

```

1 # Find feature selection
2 def findsels(itsel, pcuto):
3     ***
4     Usage: find feature selection (per file)
5     Required arguments:
6         itsel: selected string variables (DataFrame iterator)
7         pcuto: old cut numbers
8     Outputs:
9         tsels: dictionary of selected variables and given number of
10            cuts
11
12     csrow = next(itself) # iterator of selected string variables across all
13           iterations

```

```

13     tsels = dict() # selected variables and given number of cuts
14
15     citer = -1 # current iteration
16
17     while True:
18         try:
19             if csrow.aselect == 1: # for selected variable
20                 if csrow.ITER != citer:
21                     citer = csrow.ITER
22                     tsels[citer] = {
23                         'variables': list(), # selected feature
24                         'types': list(), # type of selected feature
25                         'js': list(), # selected index
26                         'ps': list() # given cut number
27                     }
28                     tsels[citer]['variables'].append(csrow.variable)
29                     tsels[citer]['types'].append(csrow.type)
30                     tsels[citer]['js'].append(csrow.jnew)
31                     tsels[citer]['ps'].append(pcuto[csrow.jnew-1])
32             csrow = next(itself) # update DataFrame iterator
33         except StopIteration:
34             break
35
36     return tsels

```

Code 4.7: Cuts or split values (module/model/findcuts.py)38

```

1 import numpy as np
2 import pandas as pd
3
4 # Find cuts and groups
5 def findcuts(tsels, itcont, itcat, intvclosed='neither', intvsubtype='
   float32'):
6     ...
7     Usage: find cuts and groups (per file)
8     Required arguments:

```

```

9      tsels: dictionary of selected variables and given number of
10     cuts
11     itcont: full continuous cuts (DataFrame iterator)
12     itcat: full categorical cuts (DataFrame iterator)
13     Optional arguments:
14     intvclosed: types of Pandas interval sides (values: 'left', '
15       right', 'both', 'neither')
16     intvsubtype: types of Pandas interval bounds (subtype of pandas.
17       IntervalDtype)
18     Outputs:
19     tcuts: dictionary of cuts and groups along all selected
20       features
21     ...
22
23     ccontrow = next(itcont) # iterator of full continuous cuts across all
24     iterations
25     ccatrow = next(itcat) # iterator of full categorical cuts across all
26     iterations
27     tcuts = dict() # cuts and groups along all selected features
28
29     for citer, sel in tsels.items(): # cuts across all selected features
30       tcuts[citer] = dict()
31       for ind, j in enumerate(sel['js']):
32         tcuts[citer][j] = {
33           'variable': tsels[citer]['variables'][ind],
34           'type': tsels[citer]['types'][ind],
35           'cuts': list(),
36           'groups': dict()
37         }
38
39     # Cuts
40     while ccontrow.iter < citer: # previous iteration may select no
41       continuous feature
42     ccontrow = next(itcont)
43     while ccatrow.iter < citer: # previous iteration may select no
44       categorical feature

```

```

37         ccatrow = next(itcat)
38     for jcur in sorted(sel['js']): # numerically sorted features
39         selected
40         cuts = tcuts[citer][jcur]['cuts'] # list of cuts along specific
41             selected feature
42         try: # iterate over full continuous cuts
43             while ccontrow.iter == citer:
44                 if ccontrow.j > jcur: # seek no more than current
45                     feature
46                     break
47                 else:
48                     if ccontrow.j == jcur: # at current selected feature
49                         cuts.append(ccontrow.bc) # continuous feature
50                         seen
51                         ccontrow = next(itcont) # update DataFrame iterator
52             except StopIteration:
53                 pass
54             try: # iterate over full categorical cuts
55                 while ccatrow.iter == citer:
56                     if ccatrow.j > jcur: # seek no more than current feature
57                         break
58                     else:
59                         if ccatrow.j == jcur: # at current selected feature
60                             cuts.append(ccatrow.v) # categorical feature seen
61                             ccatrow = next(itcat) # update DataFrame iterator
62             except StopIteration:
63                 pass
64
65         # Groups
66         pcutdc = dict(zip(tsels[citer]['js'], tsels[citer]['ps'])) # cut
67             numbers along selected features
68     for j, info in tcuts[citer].items():
69         pnum = pcutdc[j] # number of cuts on current selected feature
70         cuts = info['cuts']
71         if info['type'] == 'cont': # continuous feature
72             excuts = [-np.inf] + cuts + [np.inf]

```

```

68         intvs = pd.arrays.IntervalArray.from_breaks(
69             breaks=excuts,
70             copy=False, # default: False
71             closed=intvclosed, # types of Pandas interval sides
72             dtype=pd.IntervalDtype(subtype=intvsubtype) # types of
73                 Pandas interval bounds
74             )
75             info['groups'] = {gr: intvs[gr] for gr in range(pnum+1)}
76             else: # categorical feature
77                 info['groups'] = {gr: set() for gr in range(pnum+1)}
78                 for val, gr in enumerate(cuts):
79                     info['groups'][gr].add(val) # categorical value in cut/
80                         group
81
82     return tcuts

```

Code 4.8: True decision regions (module/model/findtregs.py)<sup>38</sup>

```

1 import numpy as np
2 import pandas as pd
3
4 from module.operation.xutil import max_dictval, itvpos
5
6
7 # Calculate new true decision regions and predictions (truly correct)
8 def findtregs(tsels, tcuts, df, pdtype=np.int16):
9     '''
10         Usage: calculate new true decision regions and predictions (per
11             file)
12             Required arguments:
13                 tsels: dictionary of selected variables and given number of
14                     cuts
15                 tcuts: dictionary of cuts and groups along all selected
16                     features

```

```

14         df: training dataset including target variable (DataFrame, not
15             iterator)
16
17     Optional arguments:
18         pdtype: NumPy data type of cut number (default: np.int16)
19
20     Outputs:
21         ttregs: dictionary of new true decision regions and their
22             predicted classes
23
24     ...
25
26
27     ttregs = dict() # new true regions with predicted classes (truly
28             correct)
29
30     classes = df['class'].unique() # all possible classes
31
32
33     for citer in tsels.keys():
34
35         regs = pd.Series([0]*len(df))
36
37         js = tsels[citer]['js']
38
39         pcutn = np.array(tsels[citer]['ps'], dtype=pdtype) # new cut
40             numbers
41
42         pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=pdtype) #
43             cumulative number of new box regions
44
45         BN = np.prod(pcutn+1) # number of new regions
46
47
48         # Convert base representation of decision region to base 10
49
50         for ind, j in enumerate(js):
51
52             info = tcuts[citer][j]
53
54             attr = info['variable']
55
56             cuts = info['cuts']
57
58             if info['type'] == 'cont': # continuous feature
59
60                 regs = regs + pncum[ind]*df[attr].apply(lambda x: itvpos(x,
61
62                     cuts))
63
64             else: # categorical feature
65
66                 regs = regs + pncum[ind]*pd.Series([cuts[x] for x in df[attr
67
68                     ]])
69
70
71         # Find predicted classes in decision regions
72
73         ttregs[citer] = {

```

```

43         b: {
44             'classes': set(), # true predicted class set
45             'correct': 0, # number of instances correctly predicted
46             'ninst': 0, # number of training instances (total)
47             'ncinst': {n: 0 for n in range(len(classes))} # number of
48                 training instances in targets
49             } for b in range(BN)
50         }
51         for i in range(len(df)):
52             ttregs[citer][regs[i]]['ninst'] += 1 # instance in region
53             ttregs[citer][regs[i]]['ncinst'][df['class'][i]] += 1 #
54                 instance of specific target in region
55         for b in range(BN):
56             kmax, vmax = max_dictval(ttregs[citer][b]['ncinst']) # true
57                 majority voting
58             ttregs[citer][b]['classes'] = kmax # all classes that have
59                 maximum number of instances
60             ttregs[citer][b]['correct'] = vmax # maximum number of
61                 instances
62
63     return ttregs

```

Code 4.9: CPLEX decision regions (module/model/findregs.py) 106

```

1 import numpy as np
2
3 from module.operation.typecast import strtoset
4 from module.operation.calregs import calregs
5
6
7 # Calculate new cplex decision regions and predictions (partially correct)
8 def findregs(tsels, itpred, pcuto, idtype=np.int16, pdtype=np.int16):
9     ...
10    Usage: calculate new cplex decision regions and predictions (per
11          file)

```

```

11     Required arguments:
12         tsels: dictionary of selected variables and given number of
13             cuts
13         itpred: individual result of cplex prediction (DataFrame
14             iterator)
14         pcuto: old cut numbers
15     Optional arguments:
16         pdtype: NumPy data type of cut number (default: np.int16)
17         idtype: NumPy data type of index (default: np.int16)
18     Outputs:
19         tcregs: dictionary of new cplex decision regions and their
20             predicted classes
21 ...
22
22     cprow = next(itpred) # iterator of instance predictions across all
23         iterations
23     tcregs = dict() # new cplex regions with predicted classes (partially
24         correct)
24     classes = set() # set all possible classes (collected from training
25         dataset)
25
26     citer = -1 # current iteration
27
28     while True: # reported by cplex as occupied region
29         try:
30             if cprow.iter != citer: # new iteration
31                 citer = cprow.iter
32             if citer in tsels.keys(): # current iteration actually
33                 selects at least one feature
33                 keep = True # keep doing in this while loop
34                 pcutn = np.array(tsels[citer]['ps'], dtype=pdtype)
35                 sidx = np.array(tsels[citer]['js'], dtype=idtype) - 1 #
36                     index starts at 0
36                 BN = np.prod(pcutn+1) # number of new regions
37                 bns = calregs(pcuto, sidx) # new corresponding regions
38                 tcregs[citer] = {

```



Code 4.10: Classification correctness (module/model/findcorr.py)

```

1 # Find both true and recalculated cplex correctness
2 def findcorr(ttregs, tcregs):
3     """
4         Usage: find both true and recalculated cplex correctness (per file)
5         Required arguments:
6             ttregs: dictionary of new true decision regions and their
7                 predicted classes
8             tcregs: dictionary of new cplex decision regions and their
9                 predicted classes
10            Outputs:
11                tc82orr: true number of correctly classified instances per region
12                cc82orr: recalculated cplex number of correctly classified
13                    instances per region
14
15        ...
16
17        tc82orr = dict() # true correctness
18        cc82orr = dict() # cplex correctness
19        for citer, tregs in ttregs.items(): # true classification
20            tc82orr[citer] = {
21                'correct': 0,
22                'detail': {b: tregs[b]['correct'] for b in tregs.keys()}
23            }
24            tc82orr[citer]['correct'] = sum(tc82orr[citer]['detail'].values())
25        for citer, cregs in tcregs.items(): # cplex classification
26            cc82orr[citer] = {
27                'correct': 0,
28                'detail': {b: 0 for b in cregs.keys()}
29            }
30            for b in cregs.keys():
31                for soc in tcregs[citer][b]['lclasses']:
32                    cc82orr[citer]['detail'][b] = max([ttregs[citer][b]['ncinst'][c]
33                        for c in soc])
34            cc82orr[citer]['correct'] = sum(cc82orr[citer]['detail'].values())

```

```
31     return tcorr, ccorr
```

Code 4.11: Final mixed box classifier (finalbox.py)

```

1 import csv
2 import re
3 125 import pandas as pd
4
5 from module.operation.xutil import *
6 from module.operation.typecast import settostr, itvtostr, itvtodesc
7 from module.operation.calregs import calregs
8 from module.model.findsels import findsels
9 from module.model.findcuts import findcuts
10 from module.model.findtregs import findtregs
11 from module.model.findcregs import findcregs
12 from module.model.findcorr import findcorr
13
14
15 # Parameters
16 pcuto = [3,3,2] # original cut numbers across all given features
17 isexample = True # whether example is shown
18 issreport = True # whether reports of feature selection are written
19 isrreport = True # whether reports of detailed decision regions are
20           written
21
22 # Informational prefixes/postfixes
23 ts = "75305" # last digits of timestamp
24 data = "seltrain20num3each20" # data name (no file extension)
25 inprefix = f"{ts}-{data}-export-" # input filename prefix
26 inpostfix = "-mfullaltseltol-2-t-1440" # input filename postfix
27
28 # Required inputs
29 datadir = "../../../../Projects/Box Classifiers/alternative/input" # directory
30           of training instances (cplex inputs)

```

```

29  indir = "../../Projects/Box Classifiers/alternative/output" # main
     input directory (cplex results)
30  datfile = f"{data}.csv" # training dataset with target variable
31  datpredfile = f"{inprefix}predict-instance-pcont-3{inpostfix}.csv" #
     individual result of cplex prediction
32  inerrfile = f"{inprefix}error{inpostfix}.csv" # classification errors and
     performance metrics
33  inselfile = f"{inprefix}select-var-str-pcont-3{inpostfix}.csv" # selected
     string variables
34  incutcontfile = f"{inprefix}cutcont-full-pcont-3{inpostfix}.csv" #
     continuous cuts
35  incutcatfile = f"{inprefix}cutcat-full-pcont-3{inpostfix}.csv" #
     categorical cuts
36
37 # Optional inputs
38 if issreport: # reports of feature selection must be written
39     metadir = "../../Data/Encoded/metadata" # metadata directory
40     metafile = "meta-indep-ppub20enc.json" # metadata (after encoding)
          file
41     # Relabel case-insensitive NIU values for all selected categorical
          features
42     niudc = {'SS_YN': "NIU (aged below 15)", 'PEMLR': "NIU"}
43 if isrreport: # reports of detailed decision regions must be written
44     clabels = {0: 'NNN', 1: 'NNY', 2: 'NY_', 3: 'YNN', 4: 'Y1Y'}
45
46 # Required outputs
47 outdir = f"../../Outputs/Main/Box/{data}" # main output directory
48 outperffile = f"{ts}-eperf.csv" # classification performances (accuracy/
          error/time)
49 outselfile = f"{ts}-selvarfin.csv" # selected string variables, cuts and
          groups
50 outregfile = f"{ts}-predregfin.csv" # full decision regions
51
52 # Optional outputs
53 outcutcontfile = f"{ts}-cutcont.csv" # continuous cuts
54 outcutcatfile = f"{ts}-cutcat.csv" # categorical cuts

```

```

55 if issreport: # reports of feature selection must be written
56     outsrepwdfile = f"{ts}-report-sel-dup.csv" # with duplicate entries
57     outsrepndfile = f"{ts}-report-sel-nondup.csv" # with nonduplicate
58         entries
58 if isrreport: # reports of detailed decision regions
59     outrrepwdfile = f"{ts}-report-reg-dup.csv" # with duplicate entries
60     outrrepndfile = f"{ts}-report-reg-nondup.csv" # with nonduplicate
61         entries
61
62 # Create main output directory (if not exist)
63 create_dir(outdir)
64
65 # Import datasets
66 dfe = pd.read_csv(f"{indir}/{inerrfile}") # cplex classification errors
67     and performance metrics
67 dfs = pd.read_csv(f"{indir}/{inselfile}") # selected string variables
68 dfcont = pd.read_csv(f"{indir}/{incutcontfile}") # full continuous cuts
69 dfcat = pd.read_csv(f"{indir}/{incutcatfile}") # full categorical cuts
70 df = pd.read_csv(f"{datdir}/{datfile}") # training dataset including
71     target variable
71 dfp = pd.read_csv(f"{indir}/{datpredfile}") # individual result of cplex
72     prediction
72
73 # Initialize DataFrame iterators
74 itsel = dfs.itertuples() # selected string variables
75 itcont = dfcont.itertuples() # full continuous cuts
76 itcat = dfcat.itertuples() # full categorical cuts
77 itpred = dfp.itertuples() # individual result of cplex prediction
78
79 # Main execution
80 tsels = findsels(itsel, pcuto) # selected variables
81 tcuts = findcuts(tsels, itcont, itcat) # cuts along all selected features
82 ttregs = findtregs(tsels, tcuts, df) # new true regions and predicted
83     classes
83 tcregs = findcregs(tsels, itpred, pcuto) # new cplex regions and predicted
84     classes

```

```

84 tcorr, ccorr = findcorr(ttregs, tcregs) # true/cplex correctness
85
86 # Calculate performance results
87 dfen = pd.DataFrame({
88     'iter': tcorr.keys(), # iteration that selects feature
89     'taccuracy': [info['correct']*100/len(df) for info in tcorr.values()],
90         # true accuracies
91     'caccuracy': [info['correct']*100/len(df) for info in ccorr.values()],
92         # recalculated cplex accuracies
93     'terror': [len(df) - info['correct'] for info in tcorr.values()], #
94         true errors
95     'cerror': [len(df) - info['correct'] for info in ccorr.values()] #
96         recalculated cplex errors
97 })
98 dfen = pd.merge(dfen, dfe, how='outer')
99 dfen.rename(columns = {
100     'error': 'rerror', # reported cplex errors
101     'accuracy': 'raccuracy' # reported cplex accuracies
102 }, inplace=True)
103 cols = dfen.columns.tolist()
104 new_cols = cols[0:1] + cols[5:5+len(pcuto)] + cols[1:3] + cols[-6:-5] +
105     cols[3:5] + cols[-7:-6] + cols[-5:]
106 dfen = dfen[new_cols] # rearranged columns
107 dfen['ms'] = dfen['ms']/60000 # convert milliseconds to minutes
108 dfen = dfen.rename(columns={'ms':'minute'})
109
110 # Display performance results
111 print(f"\n{dfen}\n")
112
113 # Examples
114 if isexample:
115     iters = [1, 2, 15]
116     for citer in iters:
117         try:
118             print(f"Selected features (iteration {citer})\n{tsels[citer]}\n")
119         
```

```

114     print(f"Cuts (iteration {citer})\n{tcuts[citer]}\n")
115     print(f"True decision regions (iteration {citer})\n{ttregs[
116         citer]}\n")
117     print(f"Cplex decision regions (iteration {citer})\n{tcregs[
118         citer]}\n")
119     print(f"True correctness (iteration {citer})\n{tcorr[citer]}\n")
120     except KeyError:
121         print(f"Iteration {citer} selects no features\n")
122 # Export non-edited information
123 copy(f"{indir}/{incutcontfile}", f"{outdir}/{outcutcontfile}") #
124     continuous cuts
124 copy(f"{indir}/{incutcatfile}", f"{outdir}/{outcutcatfile}") # categorical
125     cuts
126 # Export performance results (accuracy/error/time)
127 dfen.to_csv(f"{outdir}/{outeperffile}", float_format=".2f", header=True,
128             index=False)
129 # Export selected variables, cuts and groups
130 with open(f"{outdir}/{outselfile}", 'w', newline='') as file:35
131     writer = csv.DictWriter(
132         file,
133         fieldnames = [
134             'iter', 'jfin', 'j', 'var', 'type',
135             'p', 'cuts', 'groups'
136         ]
137     )
138     writer.writeheader()
139 for citer, info in tsels.items():
140     cuts = [[round(cut, 2) for cut in tcuts[citer][j]['cuts']] for j in
141             info['js']]
141     groups = list()

```

```

142     for ind, j in enumerate(info['js']):
143         if info['types'][ind] == 'cont': # continuous feature
144             jgrs = dict()
145             for gr, member in tcuts[citer][j]['groups'].items():
146                 jgrs[gr] = itvtostr(member)
147             groups.append(jgrs)
148         else: # categorical feature
149             groups.append(tcuts[citer][j]['groups'])
150
151     dfstmp = pd.DataFrame({
152         'iter': citer,
153         'jfin': range(1, len(info['js'])+1), # 1, 2, ...
154         'j': info['js'], # j in cplex model
155         'variable': info['variables'],
156         'type': info['types'],
157         'p': info['ps'],
158         'cuts': cuts,
159         'groups': groups
160     })
161
162     dfstmp.to_csv(f"{outdir}/{outselfile}", mode='a', header=False, index=
163     False)
164
165     del dfstmp
166
167     # Export predicted classes and number of instances in all decision regions
168     with open(f"{outdir}/{outregfile}", 'w', newline='') as file:35
169         writer = csv.DictWriter(
170             file,
171             fieldnames = ['iter', 'reg', 'ninst', 'tpred', 'cpred',
172                           'tcorr', 'ccorr', 'ncinst']
173         )
174         writer.writeheader()
175         for citer, tregs in ttregs.items():
176             for b, treg in tregs.items():
177                 writer.writerow({
178                     'iter': citer,
179                     'reg': b,
180                     'ninst': treg['ninst'], # number of instances

```



```

207
208     # True classification accuracies and performance metrics
209     efields = ['iter', 'taccuracy', 'minute', 'acctmin', 'status']
210
211     # Groups
212     grls = list() # list of all member groups across all features and
213                 # iterations
214     for citer, scuts in tcuts.items():
215         for j, info in scuts.items(): # cuts along all selected feature
216             vartype = 'Continuous' if info['type']=='cat' else 'Categorical'
217             if info['type'] == 'cont': # continuous feature (groups not
218                 displayed for convenience)
219                 for gr, member in info['groups'].items():
220                     dc = {
221                         'iter': citer,
222                         'j': j, 'variable': info['variable'],
223                         'type': 'Continuous',
224                         'label': metadc[info['variable']]['label'],
225                         'group': gr,
226                         'member': itvtosstr(member),
227                         'desc': itvtodesc(member, decimals=0, extend=False).
228                             capitalize()
229                     }
230                     grls.append(dc)
231             else: # categorical feature (groups displayed)
232                 for gr, member in info['groups'].items():
233                     for elem in member: # all elements in group member
234                         desc = catvdc[info['variable']][str(elem)]
235                         dc = {
236                             'iter': citer,
237                             'j': j, 'variable': info['variable'],
238                             'type': 'Categorical',
239                             'label': metadc[info['variable']]['label'],
240                             'group': gr,
241                             'member': elem,

```

```

239         'desc': desc
240     }
241     grls.append(dc)
242 dfg = pd.DataFrame(grls) # group dataframe
243
244 # Report dataframe of feature selection with duplicate entries (dfrp)
245 dfsrp = pd.merge(dfen[efields], dfg) # merge two dataframes: error/
246     metric and group
247
248 # Report dataframe of feature selection with nonduplicate entries (dfn)
249 dfsrpn = nondup(
250     dfsrp,
251     ndcols=[

252         ['iter', 'taccuracy', 'minute', 'acctmin', 'status'],
253         ['j', 'variable', 'type', 'label'],
254         ['group']
255     ],
256     intcols=['iter', 'status', 'j', 'group'] # integer columns
257 )
258
259 # Export final reports of feature selection
260 dfsrp.to_csv( # with duplicate entries
261     f"{outdir}/{outsrepwdfile}",
262     25
263     float_format=".2f",
264     header=True, index=False
265 )
266
267 dfsrpn.to_csv( # with nonduplicate entries
268     f"{outdir}/{outsrepndfile}",
269     25
270     sep=',', na_rep='',
271     float_format=".2f",
272     header=True, index=False
273 )
274
275 print(f"dfsrp.head()\n") # feature selection (with duplicate entries)
276 print(f"dfsrpn.head()\n") # feature selection (with nonduplicate entries
277

```

```

273
274
275 # Export final reports of detailed decision regions (with duplicate/
   nonduplicate entries) (if specified)
276
277 if isrreport: # reports of detailed decision regions must be written
278
279     # Export final reports of detailed regions (with duplicate entries)
280     with open(f"{outdir}/{outrrepwdfile}", "w", newline='') as file:35
281         writer = csv.DictWriter(
282             file,
283             fieldnames = [
284                 'iter',
285                 'ordvars', 'strvars',
286                 'reg', 'ordreg', 'crossreg',
287                 'tpreds', 'strtspreds',
288                 'ninst'
289             ])
290         writer.writeheader()
291         for citer, tregs in ttregs.items():
292             strvars = ', '.join(tsels[citer]['variables'])
293             ps = tsels[citer]['ps']
294             qs = [0]*len(ps) # base representation of numerical decision
295             region
296             js = tsels[citer]['js']
297             for b, treg in tregs.items():
298                 grls = list() # list of group members
299                 for ind in range(len(ps)):
300                     member = tcuts[citer][js[ind]]['groups'][qs[ind]]
301                     if isinstance(member, pd._libs.interval.Interval): #
302                         Pandas interval
303                         grls.append(itvtostr(member))
304                     elif isinstance(member, set): # set
305                         grls.append(settostr(member))
306                     else:

```

```

305         raise TypeError("Cut intervals can be either Pandas
306                         intervals or sets")
307
308     writer.writerow({
309         'iter': citer,
310         'ordvars': f"({','}.join([str(j) for j in js]))}", #
311                         ordered pair of selected features
312         'strvars': strvars, # string of selected features
313         'reg': b,
314         'ordreg': f"({','}.join([str(q) for q in qs]))}", #
315                         ordered pair of numerical region
316         'crossreg': ' x '.join(grls), # cross product of
317                         features in string format
318         'tpreds': ', '.join([str(v) for v in treg['classes']]), #
319                         true predicted classes
320         'strtpreds': ', '.join([clabels[v] for v in treg['
321                         classes']]), # true predicted classes
322         'ninst': treg['ninst'] # number of training instances in
323                         region
324     })
325
326     for ind in range(len(ps)): # increment base representation
327         of region for next for loop
328         qs[ind] += 1 # increment by 1
329         if qs[ind] > ps[ind]: qs[ind] = 0 # new leading one
330         else: break # same leading one
331
332 # Export final reports of detailed regions (with nonduplicate entries)
333 dfrrp = pd.read_csv(f"{outdir}/{outrrepwdfile}")
334 dfrrpn = nondup(dfrrp, ndcols=[['iter', 'ordvars', 'strvars']], intcols
335 =[['iter']])
336 dfrrpn.to_csv( # with nonduplicate entries
337     f"{outdir}/{outrrepndfile}",
338     sep=',', na_rep='',
339     header=True, index=False
340 )

```

```

331 print(f"{{dfrrp.head()}\n") # detailed decision regions (with duplicate
      entries)
332 print(f"{{dfrrpn.head()}\n") # detailed decision regions (with nonduplicate
      entries)
333
334
335 # Reexamination of CPLEX Results
336
337 # Additional output files
338 outexffile = f"{{ts}}-exam-full.csv" # full cplex reexamination
339 outexdfile = f"{{ts}}-exam-diff.csv" # difference in new decision regions
340 outexnfile = f"{{ts}}-exam-difnum.csv" # number of difference
341
342 # Convert full coordinate to position in new feature space
343 def tonpos(citer, coord):
344     ls = list()
345     for j in tsels[citer]['js']:
346         if tcuts[citer][j]['type'] == 'cont':
347             ls.append(itvpos(coord[j-1], tcuts[citer][j]['cuts']))
348         else:
349             ls.append(tcuts[citer][j]['cuts'][coord[j-1]])
350     return tuple(ls)
351
352 # Compute new numerical region from given position to new feature space
353 def tonreg(citer, pos):
354     pcutn = np.array(tsels[citer]['ps'], dtype=np.int16)
355     pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=np.int16)
356     return np.dot(pncum, pos)
357
358 dfpn = dfp.copy() # copy of individual result of cplex prediction
359 dfpn = dfpn[dfpn['iter'].isin(tsels.keys())] # exclude iterations of no
      feature selection
360
361 nregdc = dict() # new numerical regions in all iterations
362 for citer, info in tsels.items():
363     nregdc[citer] = calregs(pcuo=pcuto,sidx=np.array(info['js'])-1)

```

```

364 dfpn['creg'] = dfpn.apply(lambda x: nregdc[x.iter][x.region], axis=1) #
    new region based on cplex result
365 dfpn['tpred'] = dfpn.apply(lambda x: ttregs[x.iter][x.creg]['classes'],
    axis=1) # true predicted class
366
367 dfc = pd.merge(df, dfpn, how='right', left_on=df.index+1, right_on='id',
    suffixes=('', '_pn')) # include instance
368 del dfc['class_pn']
369 cols = dfc.columns.tolist()
370 new_cols = cols[len(pcuto)+1:len(pcuto)+3] + cols[0:len(pcuto)+1] + cols
    [-4:]
371 dfc = dfc[new_cols]
372 dfc = dfc.rename(columns={'region': 'rreg', 'predict': 'rpred'})
373
374 dfc['coord'] = dfc.iloc[:,2:len(pcuto)+2].apply(lambda x: tuple(x), axis
    =1) # full original coordinate
375 dfc['tpos'] = dfc.apply(lambda x: tonpos(x.iter, x.coord), axis=1) # true
    position in new feature space
376 dfc['treg'] = dfc.apply(lambda x: tonreg(x.iter, x.tpos), axis=1) # true
    decision region
377
378
379 dfcd = dfc[dfc['creg'] != dfc['treg']] # new cplex region differs from new
    true region
380 dfcn = dfcd.groupby('iter').size().reset_index(name='dnum') # number of
    difference
381
382 print(f"{dfcn}\n") # display number of difference in region recalculation
383 print(f"{dfcd}\n") # display difference in new regions
384
385 # Export cplex reexamination results
386 dfc.to_csv(f"{outdir}/{outexffile}", header=True, index=False) # full
    cplex reexamination
387 dfcd.to_csv(f"{outdir}/{outexdfile}", header=True, index=False) #
    difference in new decision regions

```

```
388 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
<b>A_AGE: Age</b>					
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
<b>PEMLR: Major labor force recode</b>					
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	74	0	2	1	0

Table 5.1: Cross tabulation of sample data by preselcted variables and health insurance coverage types (continued)

Preselcted Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
7: Not in labor force - other	6	3	1	1	2
<b>SS_YN: Who received social security payments either for themselves or as 1 combined payments with other family members ?</b>					
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%

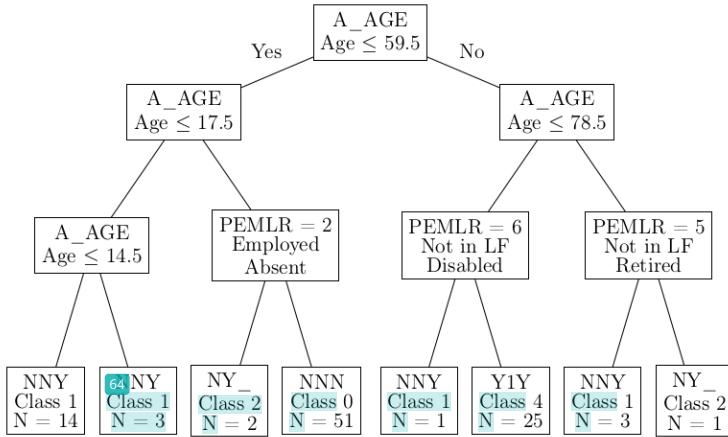


Figure 5.2: Gini-based decision tree with depth 4, 11 non-leaf nodes and 12 leaf nodes giving training accuracy of 50%

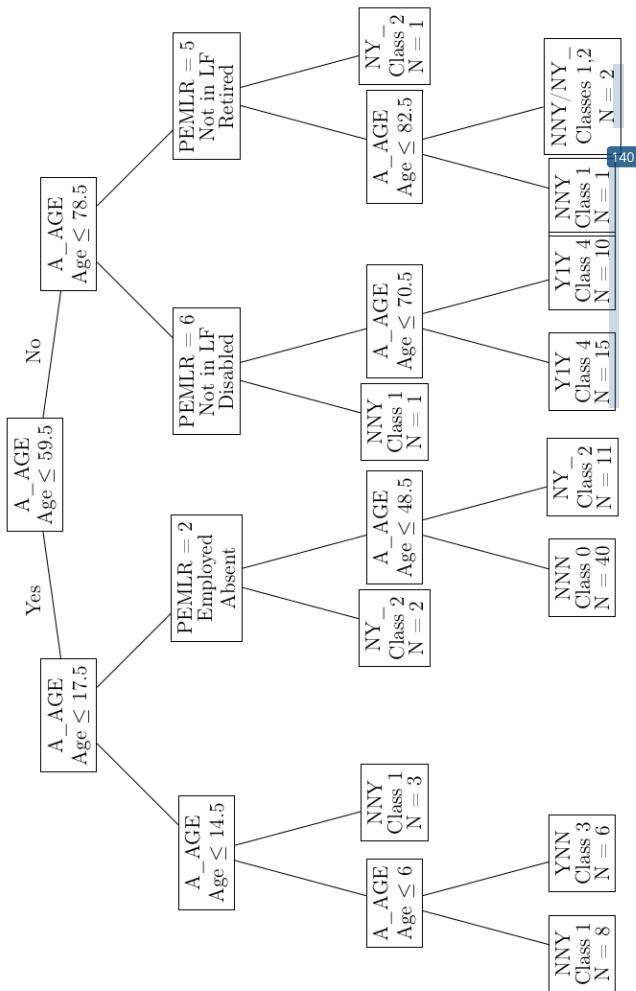
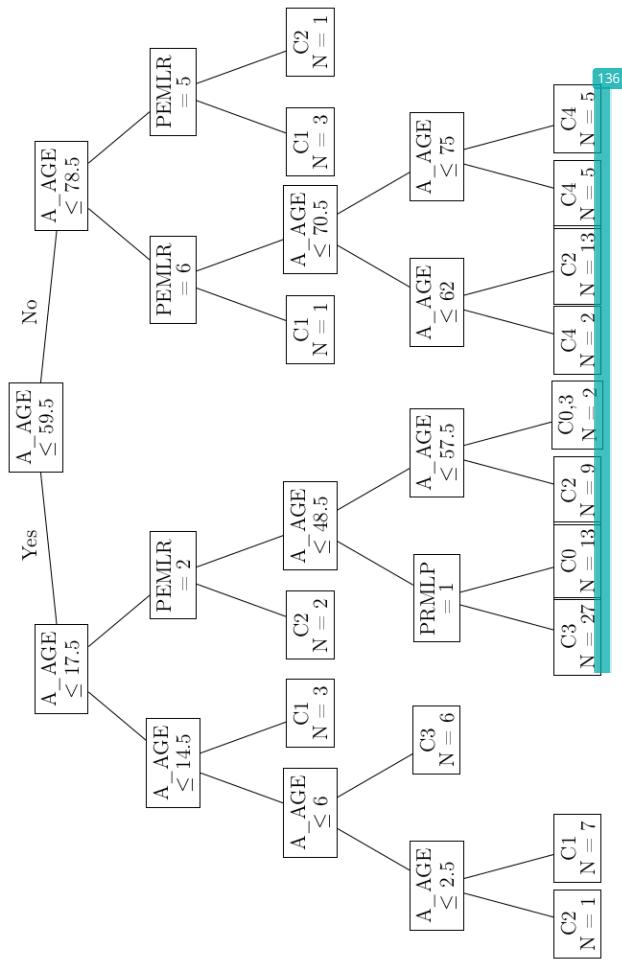


Figure 5.3: Gini-based decision tree with depth 5, 15 non-leaf nodes and 16 leaf nodes giving training accuracy of 54.4%



Code 5.1: Gini-based decision tree classifier

```

14
1 import matplotlib.pyplot as plt
2 import pandas as pd
3 import numpy as np
4 import csv
5 import os
6 from sklearn.tree import DecisionTreeClassifier, export_text, plot_tree
7
8 def create_dir(dir):
9     try:
10         os.makedirs(dir)
11     except FileExistsError:
12         pass
13
14 # Given Information
15 data_ls = []
16 data_ls.append({
17     'data': '../../Samples/cplex/seltrain20num3each20.csv',
18     'info': '../../Samples/cplex/selproc20num3co3ca3cutinfo.csv',
19     'configs': [
20         {'max_depth': 3, 'max_leaves': 16},
21         {'max_depth': 4, 'max_leaves': 16},
22         {'max_depth': 5, 'max_leaves': 16}
23     ],
24     'outdir': '../../Outputs/Main/Tree'
25 })
26 print(f"{data_ls}\n")
27
28 # Decision Tree
29 def dtree(df_data, df_info, max_depth, max_leaves, data_path='', info_path
30           =''):
31     # One-hot encoding

```

```
32     feat_cat = list(df_info[df_info['type'] == 'Categorical']['variable'])
33     for v in feat_cat:
34         df_data[v] = df_data[v].astype('category')
35     one_hot_data = pd.get_dummies(df_data[feat_cat], drop_first=True)
36     X = df_data.iloc[:,0:-(len(feat_cat)+1)].join(one_hot_data)
37     y = df_data['class']
38
39     # Build decision tree
40     clf = DecisionTreeClassifier(
41         max_depth=max_depth,
42         max_leaf_nodes=max_leaves,
43         random_state=0
44     )
45     clf.fit(X, y)
46
47     # Performance
48     score = clf.score(X, y)
49     y_pred = clf.predict(X)
50     err_ind = (y_pred != y.to_numpy().flatten()).astype(int)
51     error = np.count_nonzero(err_ind)
52     accuracy = (1-error/len(y_pred))*100
53
54     # Tree structure
55     depth = clf.tree_.max_depth
56     nodes = clf.tree_.node_count
57     leaves = clf.tree_.n_leaves
58     splits = nodes - leaves
59
60     # Decision tree summary
61     summary = {
62         'error': error, 'accuracy': accuracy, 'score': score,
63         'depth': depth,
64         'nodes': nodes, 'leaves': leaves, 'splits': splits
65     }
66
67     # Decision rules
```

```

124 rules = export_text(clf, feature_names=list(X.columns))

68
69
70 # Predicted values
71 df_pred = pd.DataFrame({
72     'y_true': df_data['class'],
73     'y_pred': y_pred,
74     'e': err_ind
75 })
76
77 # Display results
78 if data_path != '':
79     print(f"Data: {data_path}")
80 if info_path != '':
81     print(f"Info: {info_path}")
82 print(f"Maximum depth: {max_depth}")
83 print(f"Maximum number of leaves: {max_leaves}\n")
84 print(f"Categorical features: {feat_cat}")
85 print(f"X: {X.columns.values}\n")
86 print(f"Summary:")
87 print(f"\tDepth = {depth} | Leaves = {leaves}")
88 print(f"\tError = {error} | Accuracy = {accuracy} | Score = {score}")
89 print(f"\tNodes = {nodes} | Splits = {splits}\n")
90 print(f"Decision rules:\n{rules}\n")

91
92 # Return statement
93 return clf, summary, rules, df_pred
94

95 # Implementation
96 for dc in data_ls:
97
98     # Export information
99     datname = os.path.splitext(os.path.basename(dc['data']))[0] # without
100    file extension
101    outdatadir = f"{dc['outdir']}/{datname}"
102    outprefix = datname
103    outsumfile = f"{outdatadir}/{outprefix}-summary.csv"

```

```

103     outruledir = f"{outdatadir}/rules"
104     outpreddir = f"{outdatadir}/prediction"
105     outfigdir = f"{outdatadir}/figures"
106
107     # Import
108     df_data = pd.read_csv(dc['data'])
109     df_info = pd.read_csv(dc['info'])
110
111     # Exported figure formats
112     fig_formats = ['svg', 'pgf', 'pdf']
113
114     # Create directories
115     create_dir(f"{outdatadir}/rules")
116     create_dir(f"{outdatadir}/prediction")
117     for format in fig_formats:
118         create_dir(f"{outdatadir}/figures/{format}")
119
120     # Export summary file in CSV format
121     with open(outsumfile, 'w') as sumfile:
122
123         sumheader = [
124             'mdepth', 'mleaves', 'depth', 'leaves',
125             'error', 'accuracy', 'score',
126             'nodes', 'splits'
127         ]
128         writer = csv.DictWriter(sumfile, fieldnames=sumheader)  

129         writer.writeheader()
130
131     for config in dc['configs']:
132
133         # Tree configuration
134         mdepth = config['max_depth'] # depth
135         mleaves = config['max_leaves'] # number of leaves
136
137         # Postfix of exported files with specific depth and number of
138         # leaves

```

```
138     outpostfix = f"mdepth-{mdepth}-mleaves-{mleaves}"
139
140     # Decision tree
141     clf, summary, rules, df_pred = dtree(
142         df_data, df_info, mdepth, mleaves,
143         data_path=dc['data'], info_path=dc['info']
144     )
145
146     # Export summary result to CSV file
147     summary['mdepth'] = mdepth
148     summary['mleaves'] = mleaves
149     writer.writerow(summary)
150
151     # Decision rules
152     with open(f"{outruledir}/{outprefix}-rule-{outpostfix}.txt", 'w'
153     ') as rulefile:
154         rulefile.write(rules)
155
156     # Prediction
157     outpredfile = f"{outpreddir}/{outprefix}-pred-{outpostfix}.csv"
158     df_pred.index = df_pred.index + 1
159     df_pred.to_csv(outpredfile, index_label='id')
160
161     # Tree plots
162     plot_tree(clf)
163     #plot_tree(clf, label='none', impurity=False)
164     for format in fig_formats:
165         outfigfile = f"{outfigdir}/{format}/{outprefix}-fig-{outpostfix}.{format}"
166         plt.savefig(outfigfile, bbox_inches='tight')
167         #plt.show()
168
169     # Newline
170     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			
	Depth of 5	12	3	0	15			
Proposed classifier	Iteration 13	3	3	0	6	16	51	78.88
	Iteration 14	3	3	0	6			
	Iteration 15	3	3	0	6			

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
Proposed classifier	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
	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	Index	Member	Label
	Index	Symbol	Type				
2	2	PEMLR	Categorical	0	1		Employed - at work <sup>18</sup>
					3		Unemployed - on layoff
					7		Not in labor force - other
					5		Not in labor force - retired
					0	NIU	
					2		Employed - absent
					4		Unemployed - looking <sup>31</sup>
					6		Not in labor force - disabled
3	SS_YN	Categorical	0	0	2	No	
				1	1	Yes	
				2	0	NIU (aged below 15)	
3	2	PEMLR	Categorical	0	1		Employed - at work <sup>18</sup>
					3		Unemployed - on layoff
					7		Not in labor force - other
					5		Not in labor force - retired
					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	31
					6	Not in labor force - disabled	
				No			
				Yes			
					NIU (aged below 15)		
3	SS_YN	Categorical	0				
			1		1		
			2		0		
4	PEMLR	Categorical	0		1	Employed - at work	18
			1		3	Unemployed - on layoff	
			2		7	Not in labor force - other	
			3		5	Not in labor force - retired	
			4		0	NIU	
			5		2		
			6		4		
3	SS_YN	Categorical	0		6	Employed - absent	
			1		2	Unemployed - looking	31
			2		4	Not in labor force - disabled	
			1		1	No	
			0		1	Yes	
					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
5	2	PEMLR	Categorical	0	1	Employed - at work <span style="background-color: #e69138; color: white; padding: 2px;">18</span>
					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 <span style="background-color: #e69138; color: white; padding: 2px;">31</span>
					6	Not in labor force - disabled
				3	2	No
					1	Yes
				2	0	NIU (aged below 15)
6	2	PEMLR	Categorical	0	1	Employed - at work <span style="background-color: #e69138; color: white; padding: 2px;">31</span>
					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	
				2	5	Not in labor force - retired <sup>18</sup>
				3	0	NIU
				4	4	Unemployed - looking
				6	6	Not in labor force - disabled
				No	No	
				Yes	Yes	
				2	0	NIU (aged below 15)
7	2	PEMLR	Categorical	0	1	Employed - at work <sup>18</sup>
					2	Employed - absent
				4	4	Unemployed - looking
				No	NIU	
				2	0	Unemployed - on layoff
					3	
					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
8	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	6	Not in labor force - disabled <sup>28</sup>
					0	NIU
				3	3	Unemployed - on layoff
				4	4	Unemployed - looking
				7	7	Not in labor force - other
				5	5	Not in labor force - retired
				2	0	NIU (aged below 15)
				1	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	Index	Member	Label
	Index	Symbol	Type				
10	1	A_AGE	Continuous	0	( $-\infty$ , 24.01) (24.01, 40.99) (40.99, 65.99) (65.99, $\infty$ )	3 4 6 7 5 0	Unemployed - on layoff Unemployed - looking Not in labor force - disabled Not in labor force - other Not in labor force - retired NIU (aged below 15)
3	SS_YN	Categorical		3 0 2	1	Yes	
2	PEMLR	Categorical		0 1 2	1 1 7 4	Employed - absent Employed - at work Not in labor force - other Unemployed - looking	

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Index	Member	Label
	Index	Symbol	Type				
11	1	A\_AGE	Continuous	0	( $-\infty$ , 24.01) (24.01, 40.99) (40.99, 64.99) (64.99, $\infty$ )	5 0 3 6	Not in labor force - retired NIU Unemployed - on layoff Not in labor force - disabled
	2	PEMLR	Categorical	0	1 2 3	1 1 1	Above 65 Employed - absent Employed - at work
				1	7 4 5	7 4 5	Between 25 and 40 Between 41 and 64 Not in labor force - other
				2	0 3 0	0 3 0	Unemployed - looking Not in labor force - retired NIU
				3	6	3	Unemployed - on layoff 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
						Employed - absent
						Employed - at work
						Unemployed - looking
						Not in labor force - retired
						Not in labor force - other
						NIU
						Unemployed - on layoff
						Unemployed - disabled
						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	Index	Member	Label
	Index	Symbol	Type				
2	PEMLR	Categorical	0	0	2	Employed - absent	
			1	1	1	Employed - at work	
			2	3	1	Unemployed - on layoff	
			4	4	1	Unemployed - looking	
			5	5	1	Not in labor force - retired	
			7	7	1	Not in labor force - other	
			0	0	1	NIU	
				6	15	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	1	Employed - absent	
			1	1	1	Employed - at work	
			2	2	3	Unemployed - on layoff	18
			4	4	4	Unemployed - looking	

Table 5.5: Selected variables and groups of values across all iterations (continued)

Iteration	Selected Variable			Group	Index	Member	Label
	Index	Symbol	Type				
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 <sup>18</sup>	
			2	3		Unemployed - on layon	
				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} × {2}	0	NNN	48
			1	(1,0)	∅ × {2}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			2	(2,0)	{5} × {2}	2	NY <sub>—</sub>	3
			3	(3,0)	{0,2,4,6} × {2}	2	NY <sub>—</sub>	8
			4	(0,1)	{1,3,7} × {1}	2,4	NY <sub>—</sub> , YY	6
			5	(1,1)	∅ × {1}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			6	(2,1)	{5} × {1}	4	YY	16
			7	(3,1)	{0,2,4,6} × {1}	1	NNY	5
			8	(0,2)	{1,3,7} × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			9	(1,2)	∅ × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			10	(2,2)	{5} × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			11	(3,2)	{0,2,4,6} × {0}	1	NNY	14
3	(2,3)	PEMLR, SS\_YN	0	(0,0)	{1,3,7} × {2}	0	NNN	48
			1	(1,0)	∅ × {2}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
			2	(2,0)	{5} × {2}	2	NY <sub>—</sub>	3
			3	(3,0)	{0,2,4,6} × {2}	2	NY <sub>—</sub>	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)		4	{1,3,7} × {1}		2,4	NY <sub>—</sub> , Y1Y	6
5	(1,1)		5	∅ × {1}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
6	(2,1)		6	{5} × {1}	4		Y1Y	16
7	(3,1)		7	{0,2,4,6} × {1}	1		NNY	5
8	(0,2)		8	{1,3,7} × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
9	(1,2)		9	∅ × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
10	(2,2)		10	{5} × {0}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
11	(3,2)		11	{0,2,4,6} × {0}	1		NNY	14
4	(2,3)	PEMLR, SS_YN	0	(0,0)	{1,3,7} × {2}	0	NNN	48
1	(1,0)		1	∅ × {2}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
2	(2,0)		2	{5} × {2}	2		NY <sub>—</sub>	3
3	(3,0)		3	{0,2,4,6} × {2}	2		NY <sub>—</sub>	8
4	(0,1)		4	{1,3,7} × {1}	2,4		NY <sub>—</sub> , Y1Y	6
5	(1,1)		5	∅ × {1}	0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, Y1Y	0	
6	(2,1)		6	{5} × {1}	4		Y1Y	16
7	(3,1)		7	{0,2,4,6} × {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} × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
9	(1,2)			∅ × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
10	(2,2)			{5} × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
11	(3,2)			{0,2,4,6} × {0}		1	NNY	14
5	(2,3)	PEMLR, SS_YN	0	(0,0)	{1,3,7} × {2}	0	NNN	48
	1	(1,0)		∅ × {2}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
	2	(2,0)		{5} × {2}		2	NY <sub>—</sub>	3
	3	(3,0)		{0,2,4,6} × {2}		2	NY <sub>—</sub>	8
	4	(0,1)		{1,3,7} × {1}		2,4	NY <sub>—</sub> , YYY	6
	5	(1,1)		∅ × {1}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
	6	(2,1)		{5} × {1}		4	YYY	16
	7	(3,1)		{0,2,4,6} × {1}		1	NNY	5
	8	(0,2)		{1,3,7} × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
	9	(1,2)		∅ × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
	10	(2,2)		{5} × {0}		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YYY	0
	11	(3,2)		{0,2,4,6} × {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	$\{1, 2, 4\} \times \emptyset$	0,1,2,3,4
						1	$\emptyset \times \emptyset$	0,1,2,3,4
						2	$\{0, 3, 6, 7\} \times \emptyset$	0,1,2,3,4
						3	$\{5\} \times \emptyset$	0,1,2,3,4

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)		4	$\{1, 2, 4\} \times \{0, 2\}$		3	YNN	42
5	(1,1)			$\emptyset \times \{0, 2\}$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	0
6	(2,1)		6	$\{0, 3, 6, 7\} \times \{0, 2\}$		0	NNN	28
7	(3,1)			$\{3\} \times \{0, 2\}$		2	NY <sub>—</sub>	3
8	(0,2)			$\{1, 2, 4\} \times \{1\}$		2	NY <sub>—</sub>	6
9	(1,2)			$\emptyset \times \{1\}$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	0
10	(2,2)		10	$\{0, 3, 6, 7\} \times \{1\}$		1	NNY	5
11	(3,2)			$\{5\} \times \{1\}$		4	YY	16
8	(2,3)	PEMLR, SS_YN	0	(0,0)	$\{2\} \times \{2\}$	2	NY <sub>—</sub>	3
1	(1,0)			$\{1, 6\} \times \{2\}$		3	YNN	35
2	(2,0)		2	$\{0, 3, 4, 7\} \times \{2\}$		0	NNN	18
3	(3,0)			$\{5\} \times \{2\}$		2	NY <sub>—</sub>	3
4	(0,1)			$\{2\} \times \emptyset$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	0
5	(1,1)			$\{1, 6\} \times \emptyset$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	0
6	(2,1)		6	$\{0, 3, 4, 7\} \times \emptyset$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	0
7	(3,1)			$\{5\} \times \emptyset$		0,1,2,3,4	NNN, NNY, NY <sub>—</sub> , YNN, YY	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} × {0,1}		2	NY_	1
9	(1,2)			{1,6} × {0,1}		2	NY_	7
10	(2,2)			{0, 3, 4, 7} × {0,1}		1	NNY	17
11	(3,2)			{3} × {0,1}		4	Y1Y	16
9	(2,3)	PEMLR, SS_YN	0	(0,0)	{2} × {2}	2	NY_	3
			1	(1,0)	{1} × {2}	3	YNN	35
			2	(2,0)	{0, 3, 4, 6, 7} × {2}	0	NNN	18
			3	(3,0)	{5} × {2}	2	NY_	3
			4	(0,1)	{2} × Ø	0,1,2,3,4	NNN, NNY, NY_-, YNN, Y1Y	0
			5	(1,1)	{1} × Ø	0,1,2,3,4	NNN, NNY, NY_-, YNN, Y1Y	0
			6	(2,1)	{0,3,4,6,7} × Ø	0,1,2,3,4	NNN, NNY, NY_-, YNN, Y1Y	0
			7	(3,1)	{5} × Ø	0,1,2,3,4	NNN, NNY, NY_-, YNN, Y1Y	0
			8	(0,2)	{2} × {0,1}	2	NY_	1
			9	(1,2)	{1} × {0,1}	2	NY_	4
			10	(2,2)	{0,3,4,6,7} × {0,1}	1	NNY	20
			11	(3,2)	{5} × {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, YY	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 <sub>-</sub> , YNN, Y1Y	0
			1	(1,0)	(24.01, 55.99) $\times \{2\}$	2	NY <sub>-</sub>	2
			2	(2,0)	(55.99, 64.99) $\times \{2\}$	4	Y1Y	1
			3	(3,0)	(64.99, $\infty$ ) $\times \{2\}$	2	NY <sub>-</sub>	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 <sub>-</sub>	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 <sub>-</sub>	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 <sub>-</sub>	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 <sub>-</sub> ,YNN,Y1Y	0
			1	(1,0)	(24.01,55.99) $\times \{2\}$	2	NY <sub>-</sub>	2
			2	(2,0)	(55.99,64.99) $\times \{2\}$	4	Y1Y	1
			3	(3,0)	(64.99, $\infty$ ) $\times \{2\}$	2	NY <sub>-</sub>	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 <sub>-</sub>	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 <sub>-</sub>	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 <sub>-</sub>	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				Target	Reported		CPLEX		True	
	ID	A_AGE	PEMLR	SSYN		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	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
20	10	0	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
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
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	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	Region	Predict	Region	Predict	Region
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
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	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
20	10	0	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
21	85	5	1	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
22	74	5	1	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
23	64	5	1	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
24	73	5	1	1	1	22	4	5	(2, 1)	6	0, 1, 2, 3, 4
26	5	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
27	4	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
28	10	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
29	54	6	1	1	1	26	1	6	(3, 1)	7	4
30	3	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
33	17	4	1	1	1	26	1	6	(3, 1)	7	4
35	77	6	1	1	1	26	1	6	(3, 1)	7	4
36	5	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
37	80	5	1	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
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
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	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	Region	Predict	Region	Predict	Region
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	Region	Predict	Region	Predict	Region	Predict
60	56	6	1	2	26	1	6	(3, 1)	7	7	4						
64	63	1	1	3	14	2	3	(0, 1)	4	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	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	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	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
20	10	0	0	0	0	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
21	85	5	1	1	1	22	4	5	(2, 1)	6	2
22	74	5	1	1	1	22	4	5	(2, 1)	6	2
23	64	5	1	1	1	22	4	5	(2, 1)	6	2
24	73	5	1	1	1	22	4	5	(2, 1)	6	2
26	5	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
27	4	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
28	10	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
29	54	6	1	1	1	26	1	6	(3, 1)	7	4
30	3	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
33	17	4	1	1	1	26	1	6	(3, 1)	7	4
35	77	6	1	1	1	26	1	6	(3, 1)	7	4
36	5	0	0	1	1	38	1	9	(3, 2)	11	0, 1, 2, 3, 4
37	80	5	1	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
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
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	(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
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
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
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
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
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
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	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
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	Region	Predict	Region	Predict	Region
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
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
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
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 <sup>133</sup> 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.

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## APPENDICES

## CPLEX Engine Log

```
<<< setup

13 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
5 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)

-----
13 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
22 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
3 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)

-----
13 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
11 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
3 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
11 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
3 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)

-----
13 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
11 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
3 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)

-----
13 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
11 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   ---
5   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   ---
23   Elapsed time = 8.32 sec. (8694.74 ticks, tree = 6.06 MB, solutions = 5)
1551 1044   infeasible           -38.0000   -538.6066  323452   ---

```

```

23
Performing restart 1

```

```

Repeating presolve.
Tried aggregator 1 time.
MIP Presolve eliminated 447 rows and 48 columns.
MIP Presolve modified 2098 coefficients.
11
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%
5							
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%
69							
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%
5							
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%
5							
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%
5							
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%
5 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%
5 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%
5 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%
5							
<b>Elapsed time = 342.63 sec. (351762.11 ticks, tree = 158.31 MB, solutions = 5)</b>							
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%
5							
<b>Elapsed time = 383.55 sec. (391445.00 ticks, tree = 250.41 MB, solutions = 5)</b>							
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%
5							
<b>Elapsed time = 424.74 sec. (430070.66 ticks, tree = 348.74 MB, solutions = 5)</b>							
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%
5							
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%
5							
<b>Elapsed time = 682.61 sec.</b> (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%
5							
<b>Elapsed time = 734.91 sec.</b> (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%
23							
<b>Elapsed time = 781.18 sec.</b> (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%
<b>Elapsed time = 0.56 sec. (7.69 ticks, tree = 1131.55 MB, solutions = 6)</b>							
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%
<b>Elapsed time = 4.67 sec. (3790.87 ticks, tree = 1118.48 MB, solutions = 6)</b>							
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%
<b>Elapsed time = 18.01 sec. (13637.71 ticks, tree = 1129.36 MB, solutions = 6)</b>							
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%
<b>Elapsed time = 30.67 sec. (23289.65 ticks, tree = 1133.67 MB, solutions = 6)</b>							
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%
5							
<b>Elapsed time = 42.20 sec.</b> (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%
5							
<b>Elapsed time = 56.00 sec.</b> (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%
5							
<b>Elapsed time = 69.11 sec.</b> (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%
5						
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%
5						
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%
23						
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%
5	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%
5	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%
130	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%
5
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 ./cpjhGkJOU created)
```

```

GUB cover cuts applied: 872
3
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)

```
-----  

13 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%
2							
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%
2							
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 -308.4527 287 -42.0000 -376.5778 16861750 796.61%
64161 56427 -364.4031 448 -42.0000 -376.5778 16867050 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%

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```

65377 56656      -374.9636   869      -42.0000    -376.5778 16903553  796.61%
65461 56566      -354.8815   435      -42.0000    -376.5778 16906832  796.61%
9 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%
2 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%
24
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%
			2			
Elapsed time = 182.24 sec. (176632.97 ticks, tree = 2640.89 MB, solutions = 10)						
<b>Nodefile size</b> = 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%
			2			
Elapsed time = 213.20 sec. (216193.23 ticks, tree = 2715.45 MB, solutions = 11)						
<b>Nodefile size</b> = 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)						
<b>Nodefile size</b> = 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
3
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)

-----  
13 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

5 Nodes Cuts/

Node	Left	Objective	IInf	Best Integer	Best Bound	ItCnt	Gap
81435	71926	-369.0867	475	-43.0000	-376.3803	19472128	775.30%
			2				
Elapsed time = 3.10 sec. (2384.36 ticks, tree = 3375.96 MB, solutions = 13)							
<b>Nodefile size</b> = 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. (7373.28 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%

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```

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%
2
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%
2
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%
2							
<b>Elapsed time = 107.23 sec.</b> (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%
5							
<b>Elapsed time = 122.50 sec.</b> (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%
2							
<b>Elapsed time = 169.17 sec.</b> (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%
2 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%
2 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%
2 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%

```

```

2 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%
24 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%
2 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%
2
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
3
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)

-----
13 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

21 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%

```

```

2 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 9 -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%
2 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%

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```

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%
9
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%
2
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%

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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)							
<b>Nodefile size = 2828.82 MB (2551.19 MB after compression)</b>							
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)							
<b>Nodefile size = 2828.82 MB (2551.19 MB after compression)</b>							
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)							
<b>Nodefile size = 2828.82 MB (2551.19 MB after compression)</b>							
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. (136215.245 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. (174835.259 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%

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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%

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```

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%

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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%
2 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%
2 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%
2 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%

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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%
2 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%
2 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%
2 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%

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Performing restart 2

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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)
Resolve 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%
5
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%

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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%
5 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%
5 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)

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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%
5 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%
5 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%

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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%
<b>5</b>							
<b>Elapsed time = 1539.98 sec.</b> (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%
<b>Elapsed time = 1589.93 sec.</b> (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%
<b>5</b>							
<b>Elapsed time = 1642.27 sec.</b> (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%
<b>Elapsed time = 1691.83 sec.</b> (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%
<b>5</b> 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%
<b>134</b> 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%
<b>5</b> 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%
2
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%
2
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%

```

```

9
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
3
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)

-----
[13] 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

[21] Nodes
Cuts/
Node  Left      Objective  IInf  Best Integer   Best Bound   ItCnt   Gap
352957 78439    infeasible      -46.0000   -368.3667 50058943 700.80%
[2] 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%
[2] 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)							
<b>Nodefile size = 1531.15 MB (1354.94 MB after compression)</b>							
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)							
<b>Nodefile size = 1531.15 MB (1354.94 MB after compression)</b>							
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)							
<b>Nodefile size = 1531.15 MB (1354.94 MB after compression)</b>							
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%
2
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
3
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 categori
-----
13 Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File 3
CPXPARAM_MIP_Limits_Solutions 1
CPXPARAM_TimeLimit 82237.1443
CPXPARAM_MIP_Limits_TreeMemory 204800

21
Nodes Cuts/
Node Left Objective IInf Best Integer Best Bound
357813 81848 infeasible -48.0000 -368.191
2
Elapsed time = 0.66 sec. (292.33 ticks, tree = 3726.48 MB,
Nodefile size = 1679.11 MB (1484.78 MB after compression)
357826 81861 -292.1446 183 -48.0000 -368.191
357851 81885 -234.4599 151 -48.0000 -368.191
357887 81913 -152.0224 89 -48.0000 -368.190
357920 81854 -357.2824 437 -48.0000 -368.190
357957 81858 -352.0901 310 -48.0000 -368.190
358005 81876 -328.8730 208 -48.0000 -368.190
358061 81952 -365.6237 549 -48.0000 -368.190
358123 81944 -173.5007 110 -48.0000 -368.190
358187 81986 -63.5680 31 -48.0000 -368.190
358404 81869 -356.0177 335 -48.0000 -368.190
Elapsed time = 4.90 sec. (3429.12 ticks, tree = 3706.40 MB,

```

```

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%
2 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%
2 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%

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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%
2
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%
2
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%

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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%
2
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%
9
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%
2
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%

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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%
9
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%
2
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)
9
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%
2
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
3
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)

-----
13 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

21 Nodes Cuts/
Node Left Objective IInf Best Integer Best Bound ItCnt Gap
449529 148551 infeasible -49.0000 -367.9753 54370598 650.97%
2 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%
5
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%
5
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)							
<b>Nodefile size</b> = 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)							
<b>Nodefile size</b> = 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%
23							
Elapsed time = 75.01 sec. (76144.16 ticks, tree = 8099.72 MB, solutions = 33)							
<b>Nodefile size</b> = 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 148969 -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
3 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)

```
-----  
13 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
```

21 Nodes		Cuts/						
Node	Left	Objective	IInf	Best Integer	Best Bound	ItCnt	Gap	
463135	158775	infeasible		-50.0000	-367.4981	55198048	635.00%	
2								
		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%	
2		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%
2
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 2 -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%
2							
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%
2							
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%
2							
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%
2
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
3
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)

-----  
13 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

21 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%

2 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%

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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%
2
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%
2
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%

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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%
2
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%
2
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%

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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%
541763 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%

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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%
2
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%
2
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%
2
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%

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2
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%
9
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%

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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%
<b>Elapsed time = 708.04 sec. (436685.01 ticks, tree = 25451.98 MB, solutions = 37)</b>						
<b>Nodefile size = 23372.09 MB (20413.94 MB after compression)</b>						
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%
<b>Elapsed time = 769.48 sec. (474868.46 ticks, tree = 26523.33 MB, solutions = 37)</b>						
<b>Nodefile size = 24455.97 MB (21345.49 MB after compression)</b>						
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%
<b>Elapsed time = 824.55 sec. (513173.77 ticks, tree = 26881.08 MB, solutions = 37)</b>						
<b>Nodefile size = 24808.87 MB (21640.42 MB after compression)</b>						
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%
2	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%
2	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%
2	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)							
<b>Nodefile size = 29928.83 MB (26098.76 MB after compression)</b>							
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)							
<b>Nodefile size = 30835.32 MB (26886.41 MB after compression)</b>							
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)							
<b>Nodefile size = 31911.50 MB (27825.65 MB after compression)</b>							
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 9 -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%

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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%
2							
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%
2							
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%
2							
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%
2							
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%
2							
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%

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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%
2
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%
2
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%
2
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%

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5 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%
2 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%

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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%
23							
<b>Elapsed time = 2302.32 sec.</b> (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%
2							
<b>Elapsed time = 2360.98 sec.</b> (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%
<b>Elapsed time = 2430.66 sec.</b> (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)							
<b>Nodefile size = 64093.97 MB (55912.45 MB after compression)</b>							
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)							
<b>Nodefile size = 64413.10 MB (56160.38 MB after compression)</b>							
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)							
<b>Nodefile size = 66752.03 MB (58218.78 MB after compression)</b>							
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%

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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%

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5 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%
2 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%

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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)							
<b>Nodefile size = 81452.99 MB (71050.24 MB after compression)</b>							
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)							
<b>Nodefile size = 82996.73 MB (72399.07 MB after compression)</b>							
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)							
<b>Nodefile size = 84914.94 MB (74090.46 MB after compression)</b>							
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%

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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%
2
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%
2
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%
2
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%

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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%

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5 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%
2 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%

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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%
2							
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%
2							
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%
2							
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%
<b>Elapsed time = 4149.17 sec. (2536284.58 ticks, tree = 111606.07 MB, solutions = 37)</b>							
<b>Nodefile size = 109464.13 MB (95628.95 MB after compression)</b>							
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%
<b>Elapsed time = 4216.83 sec. (2574439.80 ticks, tree = 113971.04 MB, solutions = 37)</b>							
<b>Nodefile size = 111820.30 MB (97713.78 MB after compression)</b>							
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%
<b>Elapsed time = 4283.62 sec. (2612607.16 ticks, tree = 116452.58 MB, solutions = 37)</b>							
<b>Nodefile size = 114352.58 MB (99959.10 MB after compression)</b>							
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%

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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%
2 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%
2 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%
2 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%

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5
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 91445153 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%
2
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%

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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%
2							
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%
2							
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%
2							
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%
2							
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%
2							
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%

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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%

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5 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%
2 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%
2 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%

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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%
2							
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%
2							
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%
2							
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%

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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%
2 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%
2 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%
2 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%

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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%
2 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%
2 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%
2 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%

```

```

5
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
3
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

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