

# PhD Dissertation

*by* Songkomkrit Chaiyakan

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HIGHLY ACCURATE LINEAR CLASSIFIER WITH APPLICATIONS IN HEALTH  
INSURANCE COVERAGE

Songkomkrit Chaiyakan

**A1**  
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for the Degree of Doctor of Philosophy Program  
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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 2020 Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC) health insurance dataset with, as a result of the exponential time complexity of the model, only three independent variables univariately preselected by the SelectKBest technique. Compared to decision tree classifiers of different depths, the proposed classification model can keep a balance between the number of total splitting values and the number of decision boxes, and it achieves a relatively high training accuracy at the expense of significantly high computational time and storage usage. Nonetheless, both give the same set of contributing factors. The fast algorithm of decision box merging is also suggested when the number of selected features can be further reduced after optimization.

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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.** [35](#) 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  $I(X; Y)$  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. Unless the default private key `id_rsa` is used for authentication, a `Host` (named host) must be specified <sup>152</sup> in the configuration file `~/.ssh/config` by, for example, `HostName`, `User` (username) and `IdentityFile` (path to a private key file). The `Host` field can have wildcard patterns to match multiple hosts. If it contains an IP address or a domain name, the `HostName` field becomes unnecessary.

```
Host <named_host>
  HostName <hostname>
  User <username>
  IdentityFile <private_keypath>
```

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. An SSH connection may be refused in the case of loose private key permissions to prevent privilege escalation attacks. In order to resolve this issue, the principle of least privilege (PoLP) should always 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 can be granted up to everyone.

In Linux, there are three POSIX permission levels: owner, group and other. Each level is represented by three permission bits: read (r), write(w) and execute (x). They are usually rewritten in base 10, ranging from 0 to 7. <sup>120</sup> <sup>58</sup> 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 should also be nontransferable. In this dissertation, a key pair is generated on a personal computer (PC) on which the key owner is the only administrator. Under this circumstance, the private key is not accessible to the SYSTEM account. Furthermore, the Administrators group can only read, but neither change nor delete, its content, regular and extended attributes, and permissions. This set of access privileges on the public key can also be granted up to the Everyone group and the SYSTEM account.

```

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	64 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 <sup>10</sup> with a 64-bit 8-vCPU 4-core CPU, 64 GB RAM and 250 GB SSD persistent disk running on Ubuntu Server 24.04 LTS. The instance locates in region us-central1 (Iowa) and zone us-central1-f. The standard provisioning model, although noticeably more high-priced than the spot counterpart, is chosen to prevent VM preemption primarily because the proposed classifier has exponential time complexity, thereby requiring exceptionally high CPU utilization. The network traffic is routed in a premium tier to provide low latency. A static external IPv4 address is reserved and assigned to the instance for remote connection.

#### 3.3.2 SSH Key-Based Authentication

<sup>96</sup> 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 [88](#) [GNU Compiler Collection \(GCC\)](#) and [Clang/Low Level Virtual Machine \(LLVM\)](#). This dissertation chooses [the](#) first compiler. GCC 13 can be installed by using the Advanced Package Tool (APT), an interface to a packaging system on Debian and its derivatives such as Ubuntu.

```
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. [7](#)

```

#ifndef Py_GIL_DISABLED
struct _object {
    7
    #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
#endifdef _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
    7
    PY_UINT32_T ob_refcnt_split[2];
    #endif
};
#endifdef _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 {
    // ob_tid stores the thread id (or zero). It is also used by the
    // GC and the
    // trashcan mechanism as a linked list pointer and by the GC to
    // store the
    // computed "gc_refs" refcount.
    uintptr_t ob_tid;
    uint16_t _padding;
    PyMutex ob_mutex; // per-object lock
    uint8_t ob_gc_bits; // gc-related state
    uint32_t ob_ref_local; // local reference count
    Py_ssize_t ob_ref_shared; // shared (atomic) reference count
    PyTypeObject *ob_type;
};

#endif

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

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

```

### 3.3.3.3 String Interning

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

```

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);
7    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);/\//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, `/usr/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 `grprof` 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>
<code>LIBSQLITE3_[LIBS CFLAGS]</code>	<code>libsqLite3</code>	<code>sqlite3</code>	<code>libsqLite3-dev</code>
<code>LIBUUID_[LIBS CFLAGS]</code>	<code>libuuid</code>	<code>uuid</code>	<code>uuid-dev</code>
<code>PANEL_[LIBS CFLAGS]</code>	<code>libpanel</code>	<code>curses.panel</code>	<code>libpanel-dev</code>
<code>TCLTK_[LIBS CFLAGS]</code>	<code>TCLTK</code>		<code>tk-dev</code>
<code>ZLIB_[LIBS CFLAGS]</code>	<code>libzlib</code>	<code>gzip</code>	<code>zlib1g-dev</code>

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

```

66
export PATH=<install_dir>/bin:$PATH"
export LD_LIBRARY_PATH=<install_dir>/lib:${LD_LIBRARY_PATH}"
export LDFLAGS="-L<install_dir>/lib $LDFLAGS"

```

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

```

93
$ 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 `60 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 69 OCI Object Storage**

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

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

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

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

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

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

```
oci os object rename -ns <namespace> -bn <bucket> \
--name <obj_name> --new-name <obj_new_name>
[60] oci os object delete -ns <namespace> -bn <bucket> \
--name <obj_name>
[60] 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.

```
[58]
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
[132] <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>
```

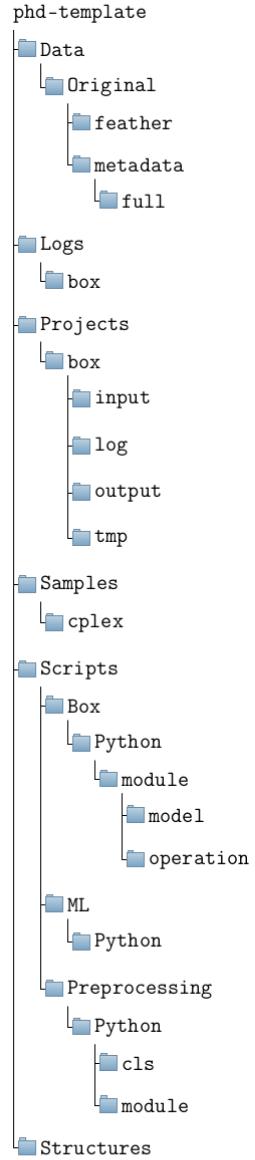
The `<project_dir>` is `Projects/box`. Thanks to its comparative low-resource consumption, using the `oplrun` executable in a terminal is preferred to starting the CPLEX Studio IDE by executing the `oplide` command. The manual backup of the CPLEX engine log is stored in the directory `Logs/box`. The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

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

There are currently 29 directories and 60 files. The directory structure is displayed in Figure 3.1.<sup>143</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 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>47</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",
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",  
1
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",  
1
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          "values": {
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     }
71 }
```

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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     },
82     "A_MARITL": {
83         "label": "Marital status",
84         "universe": "All Persons",
85         "type": "Categorical",
86         "role": "Independent",
87         "topic": "Demographics",
88         "subtopic": "Individual characteristics",
89         "values": {
90             "1": "Married - civilian spouse present",
91             "2": "Married - AF spouse present",
92             "3": "Married - spouse absent (exc.separated)",
93             "4": "Widowed",
94             "5": "Divorced",
95             "6": "Separated",
96             "7": "Never married"
97         },
98         "label": "Primary family relationship",
99         "universe": "All Persons",
100        "type": "Categorical",
101        "role": "Independent",
102        "topic": "Demographics",

```

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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",
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      "values": {
133          "1": "Civilian 15+",
134          "2": "Armed forces",
135          "3": "Children 0-14"
136      }
137  },
138  "PEAFEVER": {

```

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139      "label": "Did you ever serve on active duty in the U.S. Armed
4
140      Forces?",  

141      "universe": "A AGE greater than or equal to 17",
142      "type": "Categorical",
143      "role": "Independent",
144      "topic": "Demographics",
145      "subtopic": "Individual characteristics",
1
146      "values": {
147          "-1": "Not in universe",
148          "1": "Yes",
149          "2": "No"
150      },
151      "PEDISDRS": {
152          "label": "Does...have difficulty dressing or bathing?",
153          "universe": "PRPERTYP = 2",
154          "type": "Categorical",
155          "role": "Independent",
156          "topic": "Demographics",
157          "subtopic": "Individual characteristics",
158          "values": {
159              "-1": "Not in universe",
160              "1": "Yes",
74
161              "2": "No"
162          }
163      },
164      "PEDISEAR": {
165          "label": "Is...deaf or does ...have serious difficulty hearing?",
166          "universe": "PRPERTYP = 2",
167          "type": "Categorical",
168          "role": "Independent",
169          "topic": "Demographics",
170          "subtopic": "Individual characteristics",
171          "values": {
172              "-1": "Not in universe",
173              "1": "Yes",

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174         "2": "No"
175     },
176 },
177 "PEDISEYE": {
178     "label": "Is...blind or does...have serious difficulty seeing even
179         when wearing glasses?",  

180     "universe": "PRPERTYP = 2",
181     "type": "Categorical",
182     "role": "Independent",
183     "topic": "Demographics",
184     "subtopic": "Individual characteristics",
185     "values": {
186         "-1": "Not in universe",
187         "1": "Yes",
188         "2": "No"
189     },
190 },
191 "PEDISOUT": {
192     "label": "Because of a physical, mental, or emotional condition,
193         does...have difficulty doing errands along such as visiting a
194         doctor's office or shopping?",  

195     "universe": "PRPERTYP = 2",
196     "type": "Categorical",
197     "role": "Independent",
198     "topic": "Demographics",
199     "subtopic": "Individual characteristics",
200     "values": {
201         "-1": "Not in universe",
202         "1": "Yes",
203         "2": "No"
204     },
205 },
206 "PEDISPHY": {
207     "label": "Does...have serious difficulty Walking or climbing stairs
208     ?",
209     "universe": "PRPERTYP = 2",

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206     "type": "Categorical",
207     "role": "Independent",
208     "topic": "Demographics",
209     "subtopic": "Individual characteristics",
210     "values": {
211         "-1": "Not in universe",
212         16 "1": "Yes",
213         "2": "No"
214     }
215 },
216 "PEDISREM": {
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 },
231 "PRDISFLG": {
232     "label": "Does this person have any of these disability conditions?  

233     ",  

234     "universe": "PRPRTYP = 2",
235     "type": "Categorical",
236     "role": "Independent",
237     "topic": "Demographics",
238     "subtopic": "Individual characteristics",
239     "values": {
240         "-1": "Not in universe",
241         "1": "Yes",
242         "2": "No"
243     }
244 }

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239         "2": "No"
240     }
241 },
242 "PRCITSHP": {
243     "label": "Citizenship group",
244     "universe": "All persons",
245     "type": "Categorical",
246     "role": "Independent",
247     "topic": "Demographics",
248     "subtopic": "Individual characteristics",
249     "values": [
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         "1": "White only",
266         "2": "Black only",
267         "3": "American Indian, Alaskan Native only (AI)",
268         "4": "Asian only",
269         "5": "Hawaiian/Pacific Islander only (HP)",
270         "6": "White-Black",
271         "7": "White-AI",
272         "8": "White-Asian",
273         "9": "White-HP",
274         "10": "Black-AI",

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275         "11": "Black-Asian",
276         "12": "Black-HP",
277         "13": "AI-Asian",
278         "14": "AI-HP",
279         "15": "Asian-HP",
280         "16": "White-Black-AI",
281         "17": "White-Black-Asian",
282         "18": "White-Black-HP",
283         "19": "White-AI-Asian",
284         "20": "White-AI-HP",
285         "21": "White-Asian-HP",
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     "label": "Major industry code6",6
295     "universe": "A_CLSWKR = 1-7",
296     "type": "Categorical",
297     "role": "Independent",
298     "topic": "Basic CPS items",
299     "subtopic": "Edited labor force items",
300     "values": {
301         "0": "Not in universe, or children",
302         "1": "Agriculture, forestry,fishing, and hunting",
303         "2": "Mining",
304         "3": "Construction",
305         "4": "Manufacturing",
306         "5": "Wholesale and retail trade",
307         "6": "Transportation and utilities",
308         "7": "Information",
309         "8": "Financial activities",
310         "9": "Professional and business services",

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311         "10": "Educational and health services",
312         "11": "Leisure and hospitality",
313         "12": "Other services",
314         "13": "Public administration",
315         "14": "Armed forces"
316     },
317 },
318 "A_MJ_OCC": {
319     "label": "Major occupation recode",15
320     "universe": "A_CLSWKR = 1-7",
321     "type": "Categorical",
322     "role": "Independent",
323     "topic": "Basic CPS items",
324     "subtopic": "Edited labor force items",
325     "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     "label": "Individual class of worker on first job",
342     "universe": "All persons",
343     "type": "Categorical",
344     "role": "Independent",
345     "topic": "Basic CPS items",
346     "subtopic": "Edited labor force items",

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347     "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     },  

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     }
384 }
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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": {
391     "label": "How much does ... usually earn per week at this job  
before deductions , subject to topcoding, the higher of either  
the amount of item 25a times Item 25c or the actual item 25d  
entry will be present",
392     "universe": "PRERELG=1",
393     "type": "Continuous",
394     "role": "Independent",
395     "topic": "Basic CPS items",
396     "subtopic": "Edited earnings items",
397     "values": {
398         "0": "Not in universe or children or armed forces",
399         "0001-2885": "Dollar amount"
400     }
401 },
402 "A_HRLYWK": {
403     "label": "Is ... paid by the hour on this job?",
404     "universe": "PRERELG=1",
405     "type": "Categorical",
406     "role": "Independent",
407     "topic": "Basic CPS items",
408     "subtopic": "Edited earnings items",
409     "values": {
410         "0": "Not in universe or children and armed forces",
411         "1": "Yes",
412         "2": "No"
413     }
414 },
415 "A_HRSPAY": {

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416     "label": "How much does ... earn per hour?",
417     "universe": "A_HRLYWK=1",
418     "type": "Continuous",
419     "role": "Independent",
420     "topic": "Basic CPS items",
421     "subtopic": "Edited earnings items",
422     "values": {
423       "0": "Not in universe or children or armed forces",
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": {

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

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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",
495         "4": "Unemployed, on layoff",
496         "7": "Nilf"
497     },
498 },
499 "A_UNCOV": {
500     "label": "On this job, is ... covered by a union or employee
501             association contract?",  

502     "universe": "A_UNMEM=2",
503     "type": "Categorical",
504     "role": "Independent",
505     "topic": "Basic CPS items",
506     "subtopic": "Labor force person recodes",
507     "values": {
508         "0": "Not in universe or children and armed forces",
509         "1": "Yes",
510         "2": "No"
511     },
512 },
513 "A_UNMEM": {
514     "label": "On this job, is ... a member of a labor union or of an
515             employee association similar to a union?",  

516     "universe": "PRERELG=1",
517     "type": "Categorical",
518     "role": "Independent",
519     "topic": "Basic CPS items",
520     "subtopic": "Labor force person recodes",
521     "values": {
522         "0": "Not in universe or children and armed forces",

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521         "1": "Yes",
522         "2": "No"
523     },
524 },
525 "A_UNTYPE": {
526     6,
527     "label": "Reason for unemployment",
528     "universe": "A_LFSR=3 or 4",
529     "type": "Categorical",
530     "role": "Independent",
531     "topic": "Basic CPS items",
532     "subtopic": "Labor force person recodes",
533     "values": {
534         19,
535         "0": "Not in universe or children and Armed Forces",
536         "1": "Job loser - on layoff",
537         "2": "Other job loser",
538         "3": "Job leaver",
539         "4": "Re-entrant",
540         "5": "New entrant"
541     },
542     34,
543     "A_USLHRS": {
544         "label": "How many hrs per week does ... usually work at this job?",
545         ,
546         "universe": "All persons",
547         "type": "Continuous",
548         "role": "Independent",
549         "topic": "Basic CPS items",
550         "subtopic": "Labor force person recodes",
551         8,
552         "values": {
553             "-4": "Hours vary",
554             "-1": "Not in universe",
555             "00": "None, no hours",
556             "01-99": "Entry"
557         }
558     },
559     "A_WKSCH": {

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556     "label": "6 Labor force by time worked or lost",
557     "universe": "All persons",
558     "type": "Categorical",
559     "role": "Independent",
560     "topic": "Basic CPS items",
561     "subtopic": "Labor force person recodes",
562     "values": {
563         "0": "Not in universe",
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     }
593 }

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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 },
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     "values": {
608         "-4": "Hours vary",
609         "-1": "NIU - adult civilian",
610         "000": "NIU - children or Armed Forces or no hours",
611         "1-198": "# of hours"
612     },
613 },
614 "PEMLR": {
615     "label": "Major labor force recode",
616     "universe": "All persons",
617     "type": "Categorical",
618     "role": "Independent",
619     "topic": "Basic CPS items",
620     "subtopic": "Labor force person recodes",
621     "values": {
622         "0": "NIU",
623         "1": "Employed - at work",
624         "2": "Employed - absent",
625         "3": "Unemployed - on layoff",
626         "4": "Unemployed - looking",
627         "5": "Not in labor force - retired",

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628         "6": "Not in labor force - disabled",
629         "7": "Not in labor force - other"
630     },
631 },
632 "PRCOW1": {
633     "label": "Class of worker recode-job 1",
634     "universe": "All persons",
635     "type": "Categorical",
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)",

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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",
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",

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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": "6 Longest job class of worker (recode)",
708     "universe": "All persons aged 15+",
709     "type": "Categorical",
710     "role": "Independent",
711     "topic": "Work experience",
712     "subtopic": "General",
713     "values": {
714         "0": "Niu",
715         "1": "Private",
716         "2": "Government",
717         "3": "Self-employed",
718         "4": "Without pay",
719         "5": "Never worked"
720     }
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": {

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736     "label": "1 In the weeks that ... worked how many hours did ...  

737         usually work per week?",  

738     "universe": "WKSWORK > 0",  

739     "type": "Continuous",  

740     "role": "Independent",  

741     "topic": "Work experience",  

742     "subtopic": "General",  

743     "values": {  

744         "0": "Niu",  

745         "1": "1 hour",  

746         "2-98": "2-98 hours",  

747         "99": "99 hours plus"  

748     }  

749 },  

750 "LJCW": {  

751     "label": "Longest job class of worker",  

752     "universe": "WKSWORK > 0",  

753     "type": "Categorical",  

754     "role": "Independent",  

755     "topic": "Work experience",  

756     "subtopic": "General",  

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     "label": "6 How many different weeks was ... looking for work or on  

layoff?",  

770     "universe": "NWLOOK = 1",

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770     "type": "Continuous",
771     "role": "Independent",
772     "topic": "Work experience",
773     "subtopic": "General",
774     "values": {
775         "0": "Niu",
776         "1": "1 week",
777         "2-51": "2-51 weeks",
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?", "universe": "WORKYN = 2",
784     "type": "Categorical",
785     "role": "Independent",
786     "topic": "Work experience",
787     "subtopic": "General",
788     "values": {
789         "0": "Niu",
790         "1": "Yes",
791         "2": "No"
792     }
793 },
794 "PHMEMPRS": {
795     "label": "For how many employers did ... work in 20..? if more than
796         one at same time, only count it as one employer", "universe": "WKSWORK > 0",
797     "type": "Categorical",
798     "role": "Independent",
799     "topic": "Work experience",
800     "subtopic": "General",
801     "values": {
802         "0": "Niu",
803         "1": "One employer",

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804         "2": "Two employers",
805         "3": "3 or more employers"
806     },
807 },
808 "RSNNOTW": {
809     "label": "What was the main reason ... did not work in 20..?",4
810     "universe": "WORKYN = 2",
811     "type": "Categorical",
812     "role": "Independent",
813     "topic": "Work experience",
814     "subtopic": "General",1
815     "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": {
826     "label": "Longest job class of worker (persons 15+)",15
827     "universe": "All persons aged 15+",
828     "type": "Categorical",
829     "role": "Independent",
830     "topic": "Work experience",
831     "subtopic": "General",
832     "values": {
833         "0": "Not in universe",
834         "1": "Agriculture (Wage and salary)",
835         "2": "Agriculture (Self-employed)",
836         "3": "Agriculture (Unpaid)",
837         "4": "Nonagriculture (Private household",
838         "5": "Nonagriculture (Other private)",
839         "6": "Nonagriculture (Government)",

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840         "7": "Nonagriculture (Self-employed)",
841         "8": "Nonagriculture (Unpaid)",
842         "9": "Nonagriculture (Never worked)"
843     }
844 },
845 "WEWKRS": {
846     "label": "Weeks worked recode",
847     "universe": "All persons aged 15+",
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)",42
855         "2": "Full-year worker (Part time)",42
856         "3": "Part-year worker (Full time)",42
857         "4": "Part-year worker (Part time)",42
858         "5": "Part-year worker (Nonworker)"42
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",
869     "values": {
870         "0": "Niu",
871         "1": "1 week",
872         "2-51": "2-51 weeks",
873         "52": "52 weeks"
874     }
875 },

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875     "WORKYN": {
876         "label": "Did ... work at a job or business at any time during  
13
877             20..?",  

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

879             "type": "Categorical",  

880             "role": "Independent",  

881             "topic": "Work experience",  

882             "subtopic": "General",  
1
883             "values": {
884                 "0": "Niu",
885                 "1": "Yes",
886                 "2": "No"
887             }
888         },
889         "WRK_CK": {
890             "label": "Worked last year recode, including temporary and part-  
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  
even for a few days during 20..?",  

904         "universe": "WORKYN = 2",
905         "type": "Categorical",  

906         "role": "Independent",  

907         "topic": "Work experience",
908         "subtopic": "General",

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908     "values": {  

909         "0": "Niu",  

910         "1": "Yes",  

911         "2": "No"  

912     },  

913 },  

914 "ERN_OTR": {  

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

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

917     "type": "Categorical",  

918     "role": "Independent",  

919     "topic": "Income",  

920     "subtopic": "Earnings",  

921     "values": {  

922         "0": "Niu",  

923         "1": "Yes",  

924         "2": "No"  

925     },  

926 },  

927 "ERN_SRCE": {  

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",  

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": {  


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

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975         "0": "None or Niu",
976         "-999999-999999": "Farm self employment"
977     },
978 },
979 "FRMOTR": {
980     "label": "Receiving farm self-employment from secondary source",
981     "universe": "ERN_OTR = 1",
982     "type": "Categorical",
983     "role": "Independent",
984     "topic": "Income",
985     "subtopic": "Earnings",
986     "values": {
987         "6": "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"
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",

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1011     "values": {
1012         "6": "Niu",
1013         "1": "Yes",
1014         "2": "No"
1015     }
1016 },
1017 "PEARNVAL": {
1018     "label": "Total persons earnings",
1019     "universe": "All persons aged 15+",
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         "-999999-999999": "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",

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1045     "type": "Continuous",
1046     "role": "Independent",
1047     "topic": "Income",
1048     "subtopic": "Earnings",
1049     "values": {
1050         "0": "None or niu;"34
1051         "-99999-99999": "Own business self employment"
1052     }
1053 },
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",
1
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": {

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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",
1090         "1": "Yes",
1091         "2": "No"
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"

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1115         }
1116     },
1117     "WSAL_YN": {
1118         "label": "Receiving wage and salary earnings",
1119         "universe": "ERN_YN=1 or WAGEOTR=1",
1120         "type": "Categorical",
1121         "role": "Independent",
1122         "topic": "Income",
1123         "subtopic": "Earnings",
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",

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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",
1160     "topic": "Income",
1161     "subtopic": "Other income",
1162     "values": {
1163         "0": "None or niu",
1164         "1-999999": "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",

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1185     "topic": "Income",
1186     "subtopic": "Other income",
1187     "values": {
1188         "0": "None or niu",
1189         "1-9999999": "Dollar amount"
1190     }
1191 },
1192 "DIS_SC1": {
1193     "label": "What was the source of disability income?",
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": {

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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",
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     }

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1257     },
1258
1259     "DIS_YN": {
1260         "label": "Other than social security did ... receive any income in
1261             20.. as a result of health problems?",
1262         "universe": "All Persons aged 15+",
1263         "type": "Categorical",
1264         "role": "Independent",
1265         "topic": "Income",
1266         "subtopic": "Other income",
1267         "values": {
1268             "0": "Niu",
1269             "1": "Yes",
1270             "2": "No"
1271         }
1272     },
1273     "DIV_VAL": {
1274         "label": "How much did ... receive in dividends from stocks or
1275             mutual funds during 20.. ?",
1276         "universe": "DIV_YN = 1",
1277         "type": "Continuous",
1278         "role": "Independent",
1279         "topic": "Income",
1280         "subtopic": "Other income",
1281         "values": {
1282             "0": "None or niu",
1283             "1-999999": "Dividends"
1284         }
1285     },
1286     "DIV_YN": {
1287         "label": "Did ... receive dividends?",
1288         "universe": "All Persons aged 15+",
1289         "type": "Categorical",
1290         "role": "Independent",
1291         "topic": "Income",
1292         "subtopic": "Other income",
1293         "values": {

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1291         "0": "Niu",
1292         "1": "Yes",
1293         "2": "No"
1294     },
1295 },
1296 "DSAB_VAL": {
1297     "label": "Total amount of disability income received, combined
1298     amounts in edited sources one and two",
1299     "universe": "DIS_VAL1>0 OR DIS_VAL2>0",
1300     "type": "Continuous",
1301     "role": "Independent",
1302     "topic": "Income",
1303     "subtopic": "Other income",
1304     "values": {
1305         "0": "None or niu",
1306         "1-999999": "Disability income"
1307     },
1308 "DST_SCI": {
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 }

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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",
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         "universe": "DST_VAL2 > 0 and a_age >= 58",
1347         "type": "Categorical",
1348         "role": "Independent",
1349         "topic": "Income",
1350         "subtopic": "Other income",
1351         "values": {
1352             "0": "Niu",
1353             "1": "401k account",
1354             "2": "403b account",
1355             "3": "Roth ira",
1356             "4": "Regular ira",
1357             "5": "Keogh plan",
1358             "6": "Sep plan (simplified employee pension)",
1359             "7": "Other type of retirement account"
1360         },
1361     },

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```

1362     "DST_SC2_YNG": {
1363         "label": "Retirement Distribution source 2, person under age 58",
1364         "universe": "DST_VAL_YNG > 0 and a_age < 58",
1365         "type": "Categorical",
1366         "role": "Independent",
1367         "topic": "Income",
1368         "subtopic": "Other income",
1369         "values": {
1370             "0": "Niu",
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",

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1398     "subtopic": "Other income",
1399     1
1400     "values": {
1401         "0": "None or niu",
1402         "1- 999,999": "Amount withdrawn or distributed"
1403     }
1404
1405     "DST_VAL2": {
1406         "label": "Retirement income amount, distribution source 2",
1407         "universe": "DST_SC2 = 1",
1408         "type": "Continuous",
1409         "role": "Independent",
1410         "topic": "Income",
1411         "subtopic": "Other income",
1412         1
1413         "values": {
1414             "0": "None or niu",
1415             "1- 999,999": "Amount withdrawn or distributed"
1416         }
1417     }
1418
1419     "DST_VAL2_YNG": {
1420         "label": "Retirement Distribution amount 2, under age 58",
1421         "universe": "DST_SC2_YNG = 1",
1422         "type": "Continuous",
1423         "role": "Independent",
1424         "topic": "Income",
1425         "subtopic": "Other income",
1426         1
1427         "values": {
1428             "0": "None or niu",
1429             "1- 999,999": "Amount withdrawn or distributed"
1430         }
1431     }
1432
1433     "DST_YN": {
1434         "label": "Retirement income distribution y/n",
1435         "universe": "Persons aged 58 and over (a_age >= 58)",
1436         "type": "Categorical",
1437         "role": "Independent",
1438         "topic": "Income",

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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",
1443     "universe": "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     "label": "Total amount of educational assistance received (combined
1456         amounts in pell grant and other educational) assistance during
1457         20.. ?",
1458     "universe": "ED_YN = 1",
1459     "type": "Continuous",
1460     "role": "Independent",
1461     "topic": "Income",
1462     "subtopic": "Other income",
1463     "values": {
1464         "0": "None or niu",
1465         "1- 99,999": "Dollar amount"
1466     }
1467 },
1468 "ED_YN": {
1469     "label": "Did ... receive educational assistance?",
```

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1468     "universe": "All Persons aged 15+",
1469     "type": "Categorical",
1470     "role": "Independent",
1471     "topic": "Income",
1472     "subtopic": "Other income",
1473     "values": {
1474         "0": "Niu",
1475         "1": "Yes",
1476         "2": "No"
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     }

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1503     },
1504     "INT_VAL": {
1505         "label": "Edited total combined interest income",
1506         "universe": "INT_YN = 1",
1507         "type": "Continuous",
1508         "role": "Independent",
1509         "topic": "Income",
1510         "subtopic": "Other income",
1511         "values": {
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",
1523         "values": {
1524             "0": "Niu",
1525             "1": "Yes",
1526             "2": "No"
1527         }
1528     },
1529     "OED_TYP1": {
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",
1537         "values": {
1538             "0": "Niu",

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1538         "1": "Yes",
1539         "2": "No"
1540     },
1541 },
1542 "OED_TYP2": {
1543     "label": "Source 2 other than gi bill received (OED_TYP2-
scholarships, grants etc. from the school)",
1544     "universe": "ED_YN = 1",
1545     "type": "Categorical",
1546     "role": "Independent",
1547     "topic": "Income",
1548     "subtopic": "Other income",
1549     "values": {
1550         "0": "Niu",
1551         "1": "Yes",
1552         "2": "No"
1553     },
1554 },
1555 "OED_TYP3": {
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",
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",

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1572     "role": "Independent",
1573     "topic": "Income",
1574     "subtopic": "Other income"20,
1575     "values": {
1576         "0": "Niu",
1577         "1": "Social security",
1578         "2": "Private pensions",
1579         "3": "Afdc",
1580         "4": "Other public assistance",
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 niu",

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1608     "1-999999": "Other income"
1609
1610 },
1611 "OI_YN": {
1612     "label": "Did ... receive cash income not already covered from any
1613         other source?", 1
1614     "universe": "All Persons aged 15+", 1
1615     "type": "Categorical",
1616     "role": "Independent",
1617     "topic": "Income",
1618     "subtopic": "Other income", 1
1619     "values": {
1620         "0": "None or niu",
1621         "1": "Yes",
1622         "2": "No"
1623     }
1624 },
1625 "PEN_SC1": {
1626     "label": "Retirement income, pension source 1",
1627     "universe": "PEN_YN = 1",
1628     "type": "Categorical",
1629     "role": "Independent",
1630     "topic": "Income",
1631     "subtopic": "Other income", 8
1632     "values": {
1633         "0": "Niu",
1634         "1": "Company pension",
1635         "2": "Union pension",
1636         "3": "Federal government pension",
1637         "4": "State government pension",
1638         "5": "Local government pension",
1639         "6": "Us military pension",
1640         "7": "Us railroad retirement",
1641         "8": "Other"
1642     }
1643 },

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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",
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",

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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",
1688     "universe": "All Persons aged 15+",
1689     "type": "Categorical",
1690     "role": "Independent",
1691     "topic": "Income",
1692     "subtopic": "Other income",
1693     "values": {
1694         "0": "Niu",
1695         "1": "Yes",
1696         "2": "No"
1697     }
1698 },
1699 "PNSN_VAL": {
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",
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+",
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1714     "type": "Continuous",
1715     "role": "Independent",
1716     "topic": "Income",
1717     "subtopic": "Other income", ①
1718     "values": {
1719         "0": "None",
1720         "negative amt": "Income (loss)",
1721         "positive amt": "Income"
1722     }
1723 },
1724 "RESNSS1": { ⑧
1725     "label": "What were the reasons (you/name) (was/were) getting
1726         Social Security Income last year?",
1727     "universe": "SS_YN = 1",
1728     "type": "Categorical",
1729     "role": "Independent",
1730     "topic": "Income",
1731     "subtopic": "Other income", ①
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?",
1748     "universe": "SS_YN = 1",
1749     "type": "Categorical",

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1747     "role": "Independent",
1748     "topic": "Income",
1749     "subtopic": "Other income",
1750     "values": {
1751         "0": "Niu",
1752         "1": "Retired",
1753         "2": "Disabled (adult or child)",
1754         "3": "Widowed",
1755         "4": "Spouse",
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?",
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1780     "universe": "SSI_YN = 1",
1781     "type": "Categorical",
1782     "role": "Independent",
1783     "topic": "Income",
1784     "subtopic": "Other income",
1785     "values": {
1786         "0": "Niu",
1787         "1": "Disabled (adult or child)",
1788         "2": "Blind (adult or child)",
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 niu",
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": "Niu",
1815         "1": "Yes",

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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",
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)",

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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",
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",

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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..?",  

1895     "universe": "RNT_YN = 1",
1896     "type": "Continuous",
1897     "role": "Independent",
1898     "topic": "Income",
1899     "subtopic": "Other income",
1900     "values": {
1901         "0": "None or niu",
1902         "-9999-999999": "Rental income"
1903     },
1904 },
1905 "RNT_YN": {
1906     "label": "Did ... own any land, property, rented to others, or
1907         receive income from royalties, roomers or boarders, or from
1908         estates or trusts?",
1909     "universe": "All Persons aged 15+",
1910     "type": "Categorical",
1911     "role": "Independent",
1912     "topic": "Income",
1913     "subtopic": "Other income",
1914     "values": {
1915         "0": "Niu",
1916         "1": "Yes",
1917         "2": "No"
1918     },
1919 },
1920 "SRVS_VAL": {
1921     "label": "Total amount of survivor's income received (combined
1922         amounts in edited sources sur_val1 and sur_val2 plus the
1923         unedited sources 3 & 4 starting in 1995)",  

1924 }
```

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1919     "universe": "SUR_YN = 1",
1920     "type": "Continuous",
1921     "role": "Independent",
1922     "topic": "Income",
1923     "subtopic": "Other income",
1924     "values": {
1925         "0": "None or niu",
1926         "1-999999": "Income amount"
1927     }
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         "1-999999": "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     }

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1953     },
1954     "SSI_VAL": {
1955         "label": "How much did ... receive in supplemental security income
1956             during 20..?",  

1957         "universe": "SSI_YN = 1",
1958         "type": "Continuous",
1959         "role": "Independent",
1960         "topic": "Income",
1961         "subtopic": "Other income",
1962         "values": {
1963             "0": "None or n/a",
1964             "1-99999": "Supplemental security income"
1965         },
1966     },
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": "No",
1976             "1": "Yes",
1977             "2": "Don't know"
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": {

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1987         "0": "Niu",
1988         "1": "Yes",
1989         "2": "No"
1990     }
1991 },
1992 "SUBUC": {
1993     "label": "At any time during 20.. did ... receive any supplemental
1994     unemployment benefits?", 4
1995     "universe": "UC_YN = 1",
1996     "type": "Categorical",
1997     "role": "Independent",
1998     "topic": "Income", 1
1999     "subtopic": "Other income",
2000     "values": {
2001         "0": "Niu",
2002         "1": "Yes",
2003         "2": "No"
2004     }
2005 },
2006 "SUR_SC1": { 1
2007     "label": "What was the source of this other widow or survivor
2008     income?", 1
2009     "universe": "SUR_YN = 1",
2010     "type": "Categorical",
2011     "role": "Independent",
2012     "topic": "Income",
2013     "subtopic": "Other income",
2014     "values": {
2015         "0": "None or niu",
2016         "1": "Company or union survivor pension",
2017         "2": "Federal government",
2018         "3": "Us military retirement survivor pension",
2019         "4": "State or local gov't survivor pension",
2020         "5": "Us railroad retirement survivor pension",
2021         "6": "Worker compensation survivor",
2022         "7": "Black lung",

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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
2028              income?",
2029          "universe": "SUR_YN = 1",
2030          "type": "Categorical",
2031          "role": "Independent",
2032          "topic": "Income",
2033          "subtopic": "Other income",
2034          "values": {
2035              "0": "None or n/a",
2036              "1": "Company or union survivor pension",
2037              "2": "Federal government",
2038              "3": "Us military retirement survivor pension",
2039              "4": "State or local gov't survivor pension",
2040              "5": "Us railroad retirement survivor pension",
2041              "6": "Worker compensation survivor",
2042              "7": "Black lung",
2043              "8": "Regular payments from estates or trusts",
2044              "9": "Regular payments from annuities or paid-up life insurance
2045              ",  

2046              "10": "Other or don't know"
2047          }
2048      "SUR_VAL1": {
2049          "label": "How much did ... receive (survivor source type) during
2050              20.. ?",
2051          "universe": "SUR_YN = 1",
2052          "type": "Continuous",
2053          "role": "Independent",
2054          "topic": "Income",

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2053     "subtopic": "Other income",
2054     [8]
2054     "values": {
2055         "0": "None or niu",
2056         "1-999,999": "Survivor's income"
2057     },
2058 },
2059     "SUR_VAL2": {
2060         [1]
2060         "label": "How much did ... receive (source type) during 20.. ?",
2061         "universe": "SUR_YN = 1",
2062         "type": "Continuous",
2063         "role": "Independent",
2064         "topic": "Income",
2065         "subtopic": "Other income",
2066         [1]
2066         "values": {
2067             "0": "None or niu",
2068             "1-999,999": "Survivor's income"
2069         },
2070     },
2071     "SUR_YN": {
2072         [1]
2072         "label": "During 20.. did ... receive any survivor benefits such as
2072             widow's pensions, estates, trusts, insurance annuities, or
2072             other survivor's income?",
2073         "universe": "All Persons aged 15+",
2074         "type": "Categorical",
2075         "role": "Independent",
2076         "topic": "Income",
2077         "subtopic": "Other income",
2078         "values": {
2079             "0": "Niu",
2080             "1": "Yes",
2081             "2": "No"
2082         }
2083     },
2084     "TRDINT_VAL": {
2085         "label": "Interest amount, exlcuding retirment account interest",
2086         "universe": "INT_YN = 1",

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2087     "type": "Continuous",
2088     "role": "Independent",
2089     "topic": "Income",
2090     "subtopic": "Other income",
2091     "values": {
2092         "all": "Dollar value"
2093     }
2094 },
2095 "UC_VAL": {
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 niu",
2105         "1-99999": "Unemployment compensation"
2106     }
2107 },
2108 "UC_YN": {
2109     "label": "Any type of unemployment compensation? (Combination of
2110     subuc, strkuc, and uctot_yn)",
2111     "universe": "UC_YN = 1",
2112     "type": "Categorical",
2113     "role": "Independent",
2114     "topic": "Income",
2115     "subtopic": "Other income",
2116     "values": {
2117         "0": "Niu",
2118         "1": "Yes",
2119         "2": "No"
2120     }
2121 },
2122 "VET_TYP1": {

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2121     "label": "What type of veterans payments did .... receive? ( VET_TYP1- disability compensation?)",
2122     "universe": "VET_YN = 1",
2123     "type": "Categorical",
2124     "role": "Independent",
2125     "topic": "Income",
2126     "subtopic": "Other income",
2127     "values": {
2128         "0": "Niu",
2129         "1": "Yes",
2130         "2": "No"
2131     },
2132 },
2133 "VET_TYP2": {
2134     "label": "What type of veterans payments did .... receive? ( VET_TYP2- survivor benefits?)",
2135     "universe": "VET_YN = 1",
2136     "type": "Categorical",
2137     "role": "Independent",
2138     "topic": "Income",
2139     "subtopic": "Other income",
2140     "values": {
2141         "0": "Niu",
2142         "1": "Yes",
2143         "2": "No"
2144     },
2145 },
2146 "VET_TYP3": {
2147     "label": "What type of veterans payments did .... receive? ( VET_TYP3- veteran's pension?)",
2148     "universe": "VET_YN = 1",
2149     "type": "Categorical",
2150     "role": "Independent",
2151     "topic": "Income",
2152     "subtopic": "Other income",
2153     "values": {

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2154         "0": "Niu",
2155         "1": "Yes",
2156         "2": "No"
2157     ],
2158 },
2159 "VET_TYP4": {
2160     "label": "What type of veterans payments did .... receive? (
2161         VET_TYP4- education assistance?)",
2162     "universe": "VET_YN = 1",
2163     "type": "Categorical",
2164     "role": "Independent",
2165     "topic": "Income",
2166     "subtopic": "Other income",
2167     "values": {
2168         "0": "Niu",
2169         "1": "Yes",
2170         "2": "No"
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     },
2186     "VET_VAL": {
2187         "label": "How much did ... receive from veterans' administration
2188             during 20..?",
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2187     "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       "1-999999": "Veterans' payments"
2195     },
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",
2203     "subtopic": "Other income",
2204     "values": {
2205       "0": "Niu",
2206       "1": "Yes",
2207       "2": "No"
2208     }
2209   },
2210   "WC_TYPE": {
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",
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"

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2223     },
2224   },
2225   "WC_VAL": {
2226     "label": "How much compensation did ... receive during 20..?", 4
2227     "universe": "WC_YN = 1",
2228     "type": "Continuous",
2229     "role": "Independent",
2230     "topic": "Income",
2231     "subtopic": "Other income", 1
2232     "values": {
2233       "0": "None or niu",
2234       "1-99999": "Worker's compensation"
2235     }, 5
2236   },
2237   "WC_YN": {
2238     "label": "During 20.. did ... receive any worker's compensation 1  
payments or other payments as a result of a job related injury  
or illness?", 1
2239     "universe": "All Persons aged 15+",
2240     "type": "Categorical",
2241     "role": "Independent",
2242     "topic": "Income", 1
2243     "subtopic": "Other income", 1
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?", 1
2252     "universe": "PAW_YN = 1",
2253     "type": "Categorical",
2254     "role": "Independent",
2255     "topic": "Income",
2256     "subtopic": "Non-cash benefits",

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2257     "values": {  

2258         "0": "Niu",  

2259         "1": "TANF/AFDC",  

2260         "2": "Other",  

2261         "3": "Both"  

2262     },  

2263 },  

2264 "PAW_VAL": {  

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": {  


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2290     "label": "Was ... included in that plan?",  

2291     "universe": "PENPLAN = 1",  

2292     "type": "Categorical",  

2293     "role": "Independent",  

2294     "topic": "Income",  

2295     "subtopic": "Non-cash benefits",  

2296     "values": {  

2297         "0": "Niu",  

2298         "1": "Yes",  

2299         "2": "No"  

2300     }  

2301 },  

2302 "PENPLAN": {  

2303     "label": "Other than social security did the employer or union that  

... worked for in 20.. have a pension or other type of  

retirement plan?",  

2304     "universe": "WRK_CK = 1",  

2305     "type": "Categorical",  

2306     "role": "Independent",  

2307     "topic": "Income",  

2308     "subtopic": "Non-cash benefits",  

2309     "values": {  

2310         "0": "Niu",  

2311         "1": "Yes",  

2312         "2": "No"  

2313     }  

2314 },  

2315 "WICYN": {  

2316     "label": "Who received WIC?",  

2317     "universe": "Adult female",  

2318     "type": "Categorical",  

2319     "role": "Independent",  

2320     "topic": "Income",  

2321     "subtopic": "Non-cash benefits",  

2322     "values": {  

2323         "0": "Niu",

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2324         "1": "Received WIC",
2325         "2": "Did not receive WIC"
2326     }
2327 },
2328 "CHCARE_YN": {
2329     "label": "Paid child care was needed for this child?",
2330     "universe": "Persons age 15+ with children",
2331     "type": "Categorical",
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",

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2358     "role": "Independent",
2359     "topic": "Income",
2360     "subtopic": "Supplemental poverty measure",
2361     "values": {
2362         "0": "Niu",
2363         "1": "Yes",
2364         "2": "No"
2365     }
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?",
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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"
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": {

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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",
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": {
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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",
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": {
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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",
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",
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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",
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",

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2574         "-9999-9999999": "Dollar amount"
2575     }
2576 },
2577 "TAX_INC": {
2578     1
2579     "label": "Taxable income amount",
2580     "universe": "Tax unit head or dependent filer",
2581     "type": "Continuous",
2582     "role": "Independent",
2583     "topic": "Income",
2584     "subtopic": "Tax model items",
2585     "values": {
2586         "0": "None",
2587         "-9999-9999999": "Dollar amount"
2588     }
2589 },
2590 "PERLIS": {
2591     1
2592     "label": "Poverty level of persons (Subfamily members have primary
2593                 family recode)",
2594     "universe": "All persons",
2595     "type": "Categorical",
2596     "role": "Independent",
2597     "topic": "Poverty",
2598     "subtopic": "Poverty",
2599     1
2600     "values": [
2601         "-1": "Not in poverty universe",
2602         "1": "Below poverty level",
2603         "2": "100 - 124 percent of the poverty level",
2604         "3": "125 - 149 percent of the poverty level",
2605         "4": "150 and above the poverty level"
2606     ]
2607 },
2608 "POV_UNIV": {
2609     "label": "Poverty universe flag",
2610     "universe": "All persons",
2611     "type": "Categorical",
2612     "role": "Independent",
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2609     "topic": "Poverty",
2610     "subtopic": "Poverty",
2611     "values": {
2612         "0": "Not in poverty universe",
2613         "1": "In poverty universe"
2614     }
2615 },
2616 "HEA": {
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.

94  
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):
62    with open(jsonfile, 'w', encoding='utf-8') as f:
35        json.dump(dictfile, f, ensure_ascii=False, indent=4)
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'],
15         reverse=True
16     )

```

```

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)

```

91 import os
92 import urllib.request
93 import pandas as pd
94 import pyarrow
95
96 from module.utility import create_dir, backup_duplicate
97
98 # Import
99 def import_dataset(dataset_name, feather_dir, sas_dir='', sas_url=''):
100     filepath_feather = f"{feather_dir}/{dataset_name}.feather"
101
102     if os.path.isfile(filepath_feather):
103         print(f"{filepath_feather} is found")
104         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}"
48         if backup_dir != '':
49             backup_duplicate(
50                 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 # Cross Tabulation Analysis

```

```

21 def crosstab(df, indep_dict, cont_bins, plot, output_dir, log_filepath,
22             backup_dir=''):
23
24     dir_main = f'{output_dir}/tab-cbins-{cont_bins}'
25
26
27     123
28     for key, val in indep_dict.items():
29         fname_main = f'{key}-cbins-{cont_bins}'
30
31
32         if val['type'] == "Categorical":
33             crosstb = pd.crosstab(index=df[key].map(lambda x: val['values']
34                                   )[str(x)], columns=df['code'])
35
36         else:
37             dat = df[[key, 'code']].copy()
38             dat['bins'] = pd.cut(dat[key], bins=cont_bins)
39             crosstb = pd.crosstab(index=dat['bins'], columns=dat['code'])
40
41             del dat
42
43
44             print(key)
45             print(f"Label: {val['label']}")
46             print(f"Universe: {val['universe']}")
47             print(f"Type: {val['type']}")
48             print(f"Topic: {val['topic']}")
49             print(f"Subtopic: {val['subtopic']}")
50             print("\n")
51
52
53             print(f"Code: Employment-based plan (GRP) | Direct-purchase plan (
54                 DIR) | Public health insurance (PUB)")
55             print(crosstb)
56             '''
57
58             dir_crosstb = f'{dir_main}/cross-{cont_bins}'
59             create_dir(dir_crosstb)
60             export_dataset(
61                 crosstb,
62                 file_dir=f'{dir_crosstb}/feather', dataset_name=f'{fname_main}-
63                 cross',
64                 format='feather', info=False,
65                 backup_dir=backup_dir

```

```
53     )
54     export_dataset(
55         crosstb,
56         file_dir=f"{dir_crosstb}/csv", dataset_name=f"{fname_main}-
57             cross",
58         format='csv', info=False,
59         backup_dir=backup_dir
60     )
61     """
62
63     if plot:
64         barplot = crosstb.plot.bar()
65         barplot.legend(
66             title='(GRP,DIR,PUB)',
67             30
68             bbox_to_anchor=(1,1.02),
69             loc='upper left'
70         )
71         plt.title(val['label'])
72         plt.xlabel(key)
73         plt.ylabel('Frequency')
74         ls_format = ['svg', 'pgf', 'pdf']
75         for format in ls_format:
76             dir_fig = f"{dir_main}/figures/{format}"
77             figname = f"{key}-cbins-{cont_bins}"
78             figpath = f"{dir_fig}/{figname}.{format}"
79             create_dir(dir_fig)
80             backup_duplicate(
81                 file_dir=dir_fig, filename=figname,
82                 format=format,
83                 backup_dir=backup_dir, info=False
84             )
85             f = open(log_filepath, 'a')
86             temp = sys.stdout
87             sys.stdout = f
88             count, tries = 0, 4
```

```
88         success = False
89
90         while count < tries:
91             try:
92                 plt.savefig(figpath, bbox_inches='tight')
93                 success = True
94                 break
95             except:
96                 pass
97             count += 1
98
99             if not success:
83
100                curttime = time.strftime("%Y-%m-%d %H:%M:%S", time.localtime(time.time()))
101
102                print(f"{{curttime}} | {{key}}: {{figpath}} cannot be saved")
103
104                sys.stdout = temp
105
106                f.close()
107
108                #plt.show()
109
110
111        dftb = crosstb.reset_index().rename_axis(None, axis=1)
112        dftb[dftb.columns[1:]] = dftb[dftb.columns[1:]].astype('uint32')
113
114        export_dataset(
115            dftb,
116            file_dir=f"{dir_main}/feather", dataset_name=fname_main,
117            format='feather', info=False,
118            backup_dir=backup_dir
119        )
120
121        export_dataset(
122            dftb,
123            file_dir=f"{dir_main}/csv", dataset_name=fname_main,
124            format='csv', info=False,
125            backup_dir=backup_dir
126        )
127
128        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
2 25import 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    @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         87     self.dataset.drop(self.dataset.columns.difference(cols), axis=1,
19                           inplace=True)
20
21     def show_type(self, option='short'):
22         if option.lower() == 'full':
23             76             with pd.option_context('display.max_rows', None, 'display.
24                               max_columns', None):
25                 print(self.dataset.dtypes)
26
27             else:
28                 print(self.dataset.dtypes)
29
30
31     @staticmethod
32     def retype(ser):
33
34         if all(ser.apply(lambda x: isinstance(x, int))):
35             flag_int = True
36
37         elif all(ser.apply(lambda x: x.is_integer())):
38             flag_int = True
39
40         else:
41             flag_int = False
42
43
44         if flag_int:
45             if all(ser.apply(lambda x: x>=0)):
46                 if max(ser) <= 255:
47                     return ser.astype('uint8')
48
49                 elif max(ser) <= 65535:
50                     return ser.astype('uint16')
51
52                 else:
53                     return ser.astype('uint32')
54
55             else:
56                 if min(ser) >= -128 and max(ser) <= 127:
57                     return ser.astype('int8')
58
59                 elif min(ser) >= -32768 and max(ser) <= 32767:
60                     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 30 import pandas as pd
3 from sklearn.preprocessing import LabelEncoder
4
5 25 @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                     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                             try:

```

```

54         if int(strval) <= 0:
55             self.metadata[attr]['values'].pop(strval,
56                                         None)
56
57     except:
58         pass
58
59     if flag:
60         self.metadata[attr]['values'][0] = 'NIU'
60
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
31
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         80
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'] =
22             pcont

```

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

### 3.5.6 Exploratory Data Analysis (EDA)

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

Table 3.5. Categories of health insurance factors

Topic	Subtopic	List of Variables
Demographics	Individual characteristics	A_AGE, A_EXPRRP, A_FAMTYP, A_HGA, A_MARITL, A_PFREL, A_SEX, P_STAT, 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_SC1, DIS_SC2, DIS_VAL1, DIS_VAL2, DIS_YN, DIV_VAL, <span style="color:red">17</span> DIV_YN, DSAB_VAL, DST_SC1, DST_VAL1, DST_SC2, <span style="color:green">DST_SC2_YNG</span> , <span style="color:red">DST_VAL1</span> , <span style="color:green">DST_YNG</span> , <span style="color:red">DST_VAL2</span> , <span style="color:green">DST_VAL2_YNG</span> , DST_YN, DST_YNG, ED_VAL, ED_YN, FIN_VAL, FIN_YN, INT_VAL, INT_YN, OED_TYP1, OED_TYP2, <span style="color:red">OED_TYP3</span> , _OI_OFF, _OI_VAL, _OI_YN, PEN_SC1, PEN_SC2, PEN_VAL1, PEN_VAL2, PEN_YN, PNSN_VAL, PIOTVAL, RESNSS1, RESNSS2, <span style="color:red">RESNSS12</span> , <span style="color:green">RETCB_VAL</span> , RETCB_YN, RINT_SCI, RINT_SC2, <span style="color:red">3</span> RINT_VAL1, RINT_VAL2, RINT_YN, RNT_VAL, RNT_YN, <span style="color:green">SRVS_VAL</span> , SS_VAL, SS_YN, SSI_VAL, SSI_YN, STRKUC, <span style="color:red">17</span> SUBTC, 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, FEDTAX_AC, FEDTAX_BC, FICA, FILESTAT_MARG_TAX, PRSWKXPNS, STATETAX_A, STATETAX_B, TAX_INC
Poverty	Poverty	PERLIS, POV_UNIV
Health insurance	Health status	HEA
Supplemental poverty measure	SPM unit characteristics	SPM_ACTC

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	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 <sup>13</sup>

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
<b>A – MARITAL Marital status <sup>13</sup></b>					
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_	Y1Y	YNN
Separated	356	723	144	101
Never married	7,693	19,062	4,268	2,426
<b>A_PFREL: Primary family relationship</b> <sup>13</sup>				
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	NNY	NY_	Y1Y	YNN
<b>Universe: All Persons</b> <span style="color:red">13</span>					
Civilian 15+	12,186	28,562	12,747	8,334	62,431
Armed forces	418	16	6	1	105
Children 0-14	2,431	10,167	1,488	1,160	17,629
<b>PEAFEVER: Did you ever serve on active duty in the U.S. Armed Forces?</b> <span style="color:green">4</span>					
Universe: A_ AGE greater than or equal to 17					
Not in universe	3,207	11,462	1,745	1,320	20,376
Yes	674	3,025	1,158	1,233	2,498
No	11,154	24,258	11,338	6,942	57,291
<b>PEDISDAS: Does...have difficulty dressing or bathing?</b>					
Universe: PRPERTYP = 2					
Not in universe	2,849	10,183	1,494	1,161	17,734
Yes	98	1,545	299	233	224
No	12,088	27,017	12,448	8,101	62,207
<b>PEDISEAR: Is...deaf or does ...have serious difficulty hearing?</b> <span style="color:blue">119</span>					

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

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
White-Asian-HP	4	35	1	2	65
Black-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	5,328
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	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> <span style="color:red">13</span>					
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	NY_	Y1Y	YNN
Self-employed, unincorporated	880	974	986	246
Without pay	8	11	10	1
PRDISC: Discouraged worker recode				7
Universe: All persons				
NIU	14,880	38,437	14,165	9,452
Discouraged worker	40	83	18	4
Conditionally interested	73	159	34	28
Not available	42	66	24	11
PRUNTYPE: Individual class of worker on first job				13
Universe: All persons				
NIU	14,304	37,763	13,967	9,302
Job loser/on layoff	252	341	136	72
Other job loser	127	130	38	52
Temporary job ended	82	97	17	14
Job leaver	69	64	14	11

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
Re-entrant	162	266	62	38	275
New-entrant	39	84	7	6	74
<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	72,547
(288,5, 577,0]	412	407	218	112	1,185
(577,0, 865,5]	285	213	159	122	1,652
(865,5, 1154,0]	111	88	102	92	1,522
(1154,0, 1442,5]	64	47	42	36	979
(1442,5, 1731,0]	34	18	33	27	714
(1731,0, 2019,5]	21	15	20	16	413
(2019,5, 2308,0]	10	9	15	9	314
(2308,0, 2596,5]	13	6	20	9	201

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)		
	NNN	NY_	Y1Y
(2596.5, 2885.0]	19	13	36
		36	638
A_HRLYWK: Is ... paid by the hour on this job? <span style="border: 1px solid #ccc; padding: 2px;">4</span>			
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
A_HRSPAY: How much does ... earn per hour? <span style="border: 1px solid #ccc; padding: 2px;">6</span>			
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
			40

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NNY	NY_	Y1Y
(6929.7, 7919.8]	0	1	1	1
(7919.8, 8909.9]	0	0	0	0
(8909.9, 9900.0]	0	1	2	0
PRERLG: Earnings eligibility flag <span style="color:red">[13]</span>				
Universe: All persons	13,245	37,057	13,165	8,715
Not earnings eligible	1,790	1,688	1,076	780
Earnings eligible				
A_CIVLF: Civilian labor force				
Universe: All persons	<span style="background-color:#d9e1f2; border:1px solid #2e6b2e;">6,798</span>	30,466	8,496	5,960
Not in universe or children and Armed Forces	<span style="background-color:#d9e1f2; border:1px solid #2e6b2e;">104</span>	8,237	8,279	5,745
In universe				
A_CLSWKR: Class of worker				
Universe: PEMLR=1-3 or (PEMLR=4-7 and person worked in the last 12 <span style="color:red">[1]</span> months)	6,665	30,242	8,386	5,867
Not in universe or children and armed forces <span style="color:red">[1]</span>				

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Private	6,488	6,417	3,692	2,576	38,748
Federal government	222	120	57	138	1,708
State government	189	237	151	213	3,210
Local government	219	337	196	296	4,045
Self-employed-incorporated	325	323	756	152	1,484
Self-employed-not incorporated	880	974	986	246	1,703
Without pay	8	11	10	1	7
Never worked	39	84	7	6	74

A_EXPLF: Experienced labor force employment status	<sup>16</sup>
Universe: P_EMLR=1-4	
Not in experienced labor force	6,837
Employed	30,550
Unemployed	8,503
	5,966
	29,662
	7,506
	7,297
	5,471
	3,342
	48,871
	692
	898
	267
	187
	1,632

A_LFSR: Labor force status recode	
Universe: All persons	

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Children or Armed Forces	2,849	10,183	1,494	1,161	17,734
Working	7,178	6,826	5,136	3,181	46,957
With job, not at work	328	471	335	161	1,914
Unemployed, looking for work	479	641	138	121	909
Unemployed, on layoff	252	341	136	72	797
Nilf	3,949	20,283	7,002	4,739	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

A_WKSCH: Labor force by time worked or lost	4
Universe: All persons	
Not in universe	
At work	
With job, not at work	
Unemployed, seeks FT	
Unemployed, seeks PT	

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrolment 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>A_WKSIK: Duration of unemployment</b> <span style="color:red;">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	
<b>A_WKSTAT: Full/part-time status</b> <span style="color:red;">3</span>				
Universe: All persons				
Children or Armed Forces	2,849	10,183	1,494	1,161
			17,734	

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	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]					
(10,4, 24,8]	595	1,159	671	330	2,447
(24,8, 39,2]	1,147	1,420	805	444	4,613
(39,2, 53,6]	4,519	3,253	2,721	1,976	35,068
(53,6, 68,0]	333	257	306	147	2,691
(68,0, 82,4]	87	76	102	42	583

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

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

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="border: 1px solid red; padding: 2px;">13</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="border: 1px solid blue; padding: 2px;">15</span>					
Universe: Part time workers	<span style="border: 1px solid brown; padding: 2px;">19</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	NNY	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	101	233	156	56
Unemployed FT	618	722	197	136
Unemployed PT	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	6,959	7,099	4,733	3,023
Government	1,009	747	446	710
Self-employed	849	992	1,008	253
Without pay	17	12	15	15
Never worked	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

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	
Nearer	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] (9.9, 19.8] (19.8, 29.7] (29.7, 39.6] (39.6, 49.5] (49.5, 59.4] (59.4, 69.3] (69.3, 79.2] (79.2, 89.1] (89.1, 99.0]	6,347 354 875 1,277 5,110 673 276 77 41 5	30,317 837 1,550 1,534 3,719 461 228 48 33 18	8,296 443 858 847 2,826 578 263 74 33 23	5,648 259 390 486 2,191 336 122 33 20 10	28,472 1,576 2,922 4,780 34,221 5,584 1,929 383 222 76

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
Private	6,640	6,757	3,950	2,866
Federal	569	142	63	152
State	208	249	160	236
Local	232	356	223	322
Self employed, incorporated, yes	319	342	783	157
Self employed incorporated, no or farm	849	992	1,008	253
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
(-0.052, 5.2]	15	32	7	6
(5.2, 10.4]	13	29	4	38
(10.4, 15.6]	7	17	4	0
(15.6, 20.8]			2	17
			9	9

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(20.8, 26.0]	14	22	5	4	23
(26.0, 31.2]	3	7	1	0	2
(31.2, 36.4]	3	7	0	0	1
(36.4, 41.6]	6	17	1	1	5
(41.6, 46.8]	4	3	1	0	1
(46.8, 52.0]	78	149	30	13	74

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	NY_	Y1Y	YNN	
Part-year worker (Full time) <sup>98</sup>	1,259	1,434	695	716	4,156
Part-year worker (Part time)	907	1,757	893	491	3,308
Part-year worker (Nonworker)	3,770	19,728	6,551	4,348	10,177

WKSWORK: During 20.. in how many weeks did ... work even for a few hours? <sup>100</sup>	
(include paid vacation and sick leave as work)	
Universe: Persons 15+ with WORKYN = 1	
(-0.052, 5.2]	6,329
(5.2, 10.4]	147
(10.4, 15.6]	180
(15.6, 20.8]	229
(20.8, 26.0]	318
(26.0, 31.2]	184
(31.2, 36.4]	235
(36.4, 41.6]	300
(41.6, 46.8]	267
	30,179
	8,164
	5,588
	28,130
	110
	98
	626
	147
	147
	104
	716
	131
	748
	218
	197
	926
	117
	79
	493
	155
	111
	733
	242
	163
	1,138
	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">13</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 enrolment 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	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				
(-20767.998, 57001.8]	15,029	38,739	14,206	9,483
[57001.8, 134001.6]	6	5	29	10
(134001.6, 211001.4]	0	1	2	0
[211001.4, 288001.2]	0	0	3	1
(442000.8, 519000.6]	0	0	0	1
(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
Yes	122	105	170	70
				560

Table 3.6: Number of survey participants by health factors and five insurance coverage combinations of enrolment 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	12,482	28,473	12,583	8,265	61,976

PEARNVAL: Total persons earnings	
Universe: All persons aged 15+	
(-12083.998, 198500.8]	14,962
(198500.8, 407000.6]	53
(407000.6, 615500.4]	11
(615500.4, 824000.2]	3
(824000.2, 1032500.0]	3
(1032500.0, 1240999.8]	3
(1240999.8, 1449499.6]	0
(1449499.6, 1657999.4]	0
(1866499.2, 2074999.0]	0

SE_VAL: Amount of own business self-employment earnings from secondary	-
source	
Universe: SEOTR = 1	

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-10558.999, 46000.9]	15,027	38,736	14,220	9,484	80,099
(46000.9, 102000.8]	8	7	14	6	45
(102000.8, 158000.7]	0	2	5	2	6
(158000.7, 214000.6]	0	0	0	2	4
(214000.6, 270000.5]	0	0	0	1	1
(270000.5, 326000.4]	0	0	2	0	5
(326000.4, 382000.3]	0	0	0	0	3
(382000.3, 438000.2]	0	0	0	0	1
(494000.1, 550000.0]	0	0	0	0	1

SEMP\_VAL: Total own business self-employment earnings (combined amounts 13)

in ern-val, if ern-srce=2, and se-val)

Universe: ERN\_YN=1 or SEOTR=1

(-21117.997, 92001.7]

(92001.7, 204001.4]

(204001.4, 316001.1]

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
(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	NY_	Y1Y	YNN
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				
(-999.999, 99999.9]	15,033	38,711	14,203	9,460
(99999.9, 199999.8]	2	32	35	32
(199999.8, 299999.7]	0	2	2	1
(299999.7, 399999.6]	0	0	0	1
(399999.6, 499999.5]	0	0	1	0
(899999.1, 999999.0]	0	0	1	1
<b>DIS_SC1: What was the source of disability income? =</b>				
Universe: DIS_YN=1				
Niu	14,947	38,270	14,130	9,359
Worker's compensation	16	32	11	15
				96

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Company or union disability	10	48	19	34	123
Federal government disability	6	58	9	10	15
Us military retirement disability	18	45	10	8	12
State or local gov't employee disability	14	92	21	25	56
Us railroad retirement disability	0	6	2	0	1
Accident or disability insurance	8	32	16	17	60
Blacklung miners disability	0	0	0	1	0
State temporary sickness	3	1	2	1	9
Other or don't know	13	161	21	25	86

DIS\_SC2: What was the source of disability income? 

Universe: DIS\_YN=1

Niu

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
	0	0	1	0	0
	0	1	0	0	0
	0	2	0	1	3

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Other or don't know <sup>15</sup>	0	2	0	1	4
<b>DIS_VAL1: How much did ... receive (source type) during 20..? <span style="color:red;">-</span></b>					
Universe: DIS_SC1>0					
(-100,0,10000.0]	14,993	38,533	14,185	9,428	80,005
(10000.0, 20000.0]	26	144	25	31	78
(20000.0, 30000.0]	7	33	16	23	40
(30000.0, 40000.0]	4	13	4	4	15
(40000.0, 50000.0]	3	10	1	2	11
(50000.0, 60000.0]	1	0	0	1	1
(60000.0, 70000.0]	1	1	1	0	1
(70000.0, 80000.0]	0	1	1	1	4
(80000.0, 90000.0]	0	1	0	1	0
(90000.0, 100000.0]	0	9	8	4	10
<b>DIS_VAL2: How much did ... receive (source type) during 20..? <span style="color:red;">-</span></b>					
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	77
(20000.0, 30000.0]	7	33	17	23	44
(30000.0, 40000.0]	4	14	4	3	15
(40000.0, 50000.0]	3	10	1	2	11
(50000.0, 60000.0]	1	0	0	2	1
(60000.0, 70000.0]	1	1	1	0	1
(70000.0, 80000.0]	0	1	1	1	4
(80000.0, 90000.0]	0	1	0	1	0
(90000.0, 100000.0]	0	9	8	4	10

DST_SC1: Retirement income, distribution source 1					
Universe: DST_VAL1 > 0 and a_age >= 58					
Niu	14,982	37,052	12,699	8,267	79,685
401k account	28	684	568	499	249
403b account	0	49	39	48	20
Roth ira	2	114	99	60	24

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Regular ira	17	739	715	499	115
Keogh plan	0	1	3	3	1
Sep plan (simplified employee pension)	1	12	27	18	5
Other type of retirement account	5	94	91	101	66
DST_SC1_YNG: 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
DST_VAL2: Retirement income amount, distribution source 2 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
DST_VAL2_YNG: Retirement Distribution amount 2, under age 58	—			
Universe: DST_SC2_YNG = 1				

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(-43,0, 4300,0]	15,032	38,742	14,241	9,494	80,157
(4300,0, 8600,0]	2	1	0	1	4
(8600,0, 12900,0]	0	1	0	0	1
(21500,0, 25800,0]	0	0	0	0	1
(30100,0, 34400,0]	0	1	0	0	2
(38700,0, 43000,0]	1	0	0	0	0
DST_YN: Retirement income distribution y/n					
Universe: Persons aged 58 and over (a_age >= 58) <span style="color:red;">1</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;">1</span>					
Universe: Persons under age 58 (a_age < 58) <span style="color:red;">1</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				
(-500.0, 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, 28000.0]	14,979	38,527	13,944	9,220	78,544
(28000.0, 56000.0]	31	126	164	145	937
(56000.0, 84000.0]	16	41	60	46	281
(84000.0, 112000.0]	7	45	66	73	354
(112000.0, 140000.0]	1	4	7	10	35
(140000.0, 168000.0]	1	1	0	0	11
(168000.0, 196000.0]	0	0	0	1	1
(196000.0, 224000.0]	0	1	0	0	1
(252000.0, 280000.0]	0	0	0	0	1
INT_YN: Edited total combined interest income, y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NNY	NY_	Y1Y
Yes	3,950	9,847	7,759	5,700
No	8,654	18,731	4,994	2,635
OED_TYP1: 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
Yes	102	144	62	44
No	349	512	251	120
OED_TYP2: 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
Yes	146	211	153	61
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 -)</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>144</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
OI_VAL: How much did ... receive in other incomes <sup>6</sup>					
Universe: OI_YN = 1					
(-950.0, 95000.0]	15,033	38,744	14,240	9,488	80,149
(95000.0, 190000.0]	2	0	1	5	12
(190000.0, 285000.0]	0	0	0	1	0
(285000.0, 380000.0]	0	1	0	0	1
(380000.0, 475000.0]	0	0	0	1	1
(475000.0, 570000.0]	0	0	0	0	1
(855000.0, 950000.0]	0	0	0	0	1

OI\_YN: Did ... receive cash income not already covered from any other source?<sup>145</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	38,737	14,239	9,485	80,158
(36000.0, 72000.0]	1	6	1	7	6
(72000.0, 108000.0]	1	1	1	2	1
(108000.0, 144000.0]	0	0	0	1	0
(324000.0, 360000.0]	0	1	0	0	0
PEN_YN: Retirement income, pension y/n					
Universe: All Persons aged 15+					
Niu	2,431	10,167	1,488	1,160	17,629

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
Yes	173	2,710	1,847	2,188	1,163
No	12,431	25,868	10,906	6,147	61,373
<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	80,125
(99999,9, 199999,8]	5	22	17	36	31
(199999,8, 299999,7]	0	3	1	3	3
(299999,7, 399999,6]	0	4	1	1	1
(399999,6, 499999,5]	0	3	1	0	2
(599999,4, 699999,3]	0	2	0	0	0
(699999,3, 799999,2]	0	1	0	0	0
(899999,1, 999999,0]	0	3	2	4	3
<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

RESNSSI: 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>	
Security Income last year?	
Universe: SS_YN = 1	
Nu	15,018
Disabled (adult or child)	38,345
Widowed	14,129
Spouse	9,409
Surviving child	80,099
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	NNY	NY_	Y1Y	YNN
On behalf of surviving, dependent, or disabled child(ren) <sup>-1</sup>	11	89	22	21	47
Other (adult or child)	1	15	6	10	1
RESNSS1: What were the reasons (you/name) (was/were) getting <sup>88</sup>					
Supplemental Security Income last year?					
Universe: SSI_YN = 1					
Niu	14,976	36,504	14,140	9,303	80,055
Disabled (adult or child)	39	1,992	77	159	66
Blind (adult or child)	0	25	2	1	2
On behalf of a disabled child <sup>15</sup>	16	58	6	10	25
On behalf of a blind child <sup>15</sup>	0	2	0	0	1
Other (adult or child)	4	164	16	22	16
RESNSS12: What were the reasons (you/name) (was/were) getting <sup>88</sup>					
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	YNN
<b>RETCB_YN: Retirement contribution, y/n</b>					
Universe: All people 15 years and over					
Niu	13,470	34,901	10,249	6,228	53,437
Yes	1,034	793	1,070	1,247	21,810
No	531	3,051	2,922	2,020	4,918
<b>RINT_SC1: Interest income, retirement source 1</b>					
Universe: RINT_YN = 1					
Niu	13,470	34,901	10,249	6,228	53,437
401k account	973	1,925	1,791	1,791	19,885
403b account	60	121	118	188	2,112
Roth ira	216	421	583	292	1,465
Regular ira	163	1,063	1,207	711	1,239
Keogh plan	0	5	11	4	23
Sep plan (simplified employee pension)	19	49	98	43	305
Other type of retirement account	134	260	184	238	1,699

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
<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, 10000.0]	14,936	38,372	13,795	9,102	77,436
(10000.0, 20000.0]	51	173	178	147	1,160
(20000.0, 30000.0]	17	60	86	68	496
(30000.0, 40000.0]	9	45	56	40	274

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
(40000.0, 50000.0]	6	28	43	46	287
(50000.0, 60000.0]	3	5	16	7	85
(60000.0, 70000.0]	3	9	12	10	75
(70000.0, 80000.0]	5	13	9	17	71
(80000.0, 90000.0]	0	2	6	4	26
(90000.0, 100000.0]	5	38	40	54	255

RINT_VAL2: Interest income amt, retirement source 2					
Universe: RINT_SC2 > 0					
(-100.0, 10000.0]	15,015	38,701	14,182	9,431	79,816
(10000.0, 20000.0]	9	14	22	25	140
(20000.0, 30000.0]	0	13	14	16	44
(30000.0, 40000.0]	2	2	2	4	39
(40000.0, 50000.0]	3	6	7	3	15
(50000.0, 60000.0]	2	2	1	3	11
(60000.0, 70000.0]	1	0	1	1	14

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NNY	NY_	Y1Y
(70000, 0, 800000, 0]	0	2	2	3
(80000, 0, 90000, 0]	0	0	1	0
(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
Yes	1,565	3,844	3,992	3,267
No	11,039	24,734	8,761	5,068
RNT_VAL: How much did ... receive in income from rent after expenses during <a href="#">4s</a>				
20..?				
Universe: RNT_YN = 1				
(-11008.998, 91000.8]	15,031	38,718	14,217	9,473
(91000.8, 132000.6]	2	25	18	20
(192000.6, 293000.4]	0	1	1	0
(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
(20000.0, 40000.0]	7	39	39	48
(40000.0, 60000.0]	4	18	8	14
(60000.0, 80000.0]	0	1	3	0
(80000.0, 100000.0]	2	11	8	13
(100000.0, 120000.0]	0	1	1	0
(120000.0, 140000.0]	0	1	1	0
(140000.0, 160000.0]	0	0	0	0
(180000.0, 200000.0]	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
(8000.0, 16000.0]	185	5,828	1,913	1,388
(16000.0, 24000.0]	91	3,923	2,002	1,553
(24000.0, 32000.0]	20	1,192	846	695
(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 <sup>4</sup> strike benefits?					
Universe: UC_YN = 1					
Niu	2,431	10,167	1,488	1,160	17,629
Yes	4	10	3	4	27

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NY_	Y1Y	YNN
No	12,600	28,568	12,750	8,331
SUBUC: At any time during 20.. did ... receive any supplemental unemployment benefits? <span style="color: red;">4</span>				
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? <span style="color: red;">19</span>				
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 govt 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	NY_	Y1Y
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	42
Other or don't know	11	66	34	81
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	NNY	NY_	Y1Y
No	68	321	67	55
<b>VET_TYP2: What type of veterans payments did .... receive? (VET_TYP2_</b> 88 <b>survivor benefits?)</b>				
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 <b>veteran's pension?)</b>				
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 <b>education assistance?)</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: 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
(20000.0, 30000.0]	67	121	20	42
(30000.0, 40000.0]	23	134	24	34
(40000.0, 50000.0]	18	55	9	19
(50000.0, 60000.0]	3	8	2	2
(60000.0, 70000.0]	7	3	1	2
(70000.0, 80000.0]	4	0	1	0
(80000.0, 90000.0]	4	2	2	0
(90000.0, 100000.0]	3	6	1	2
VET_YN: Did ... receive veterans' payments?				
Universe: All Persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	271	996	198	319
No	12,333	27,582	12,555	8,016
				62,137

WC_TYPE: What was source of these payments? <span style="color: orange;">6</span>	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	NY	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 [redacted] 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	NY_	Y1Y
Niu	10,363	30,214	11,865	8,177
Received WIC	207	717	59	110
Did not receive WIC	4,465	7,814	2,317	1,208
<b>CHCARE_YN:</b> Paid child care was needed for this child? <span style="color:red;">+/-</span>				
Universe: Persons age 15+ with children				
Niu	12,604	28,578	12,753	8,335
Yes	361	1,381	252	233
No	2,070	8,786	1,236	927
<b>CHELSEW_YN:</b> Does this person have a child living outside the household? <span style="color:red;">+/-</span>				
Universe: All persons aged 15+				
Niu	2,431	10,167	1,488	1,160
Yes	386	443	163	129
No	12,218	28,135	12,590	8,206
<b>CHSP_VAL:</b> What is the annual amount of child support paid? <span style="color:red;">+/-</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	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

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	NY_	Y1Y	YNN	
(458415.6, 692622.9]	14	21	33	21	325
(692622.9, 926830.2]	4	5	16	4	98
(926830.2, 1161037.5]	4	5	11	9	87
(1161037.5, 1385244.8]	0	0	4	2	56
(1395244.8, 1629452.1]	0	1	1	2	7
(1629452.1, 1863659.4]	0	0	1	0	1
(1863659.4, 2097866.7]	0	0	1	0	6
(2097866.7, 2332074.0]	0	0	1	0	6
CTC_CRD: Child tax credit					
Universe: Tax unit head or dependent filer					
(-18.0, 1800.0]	13,956	38,047	13,477	8,913	69,728
(1800.0, 3600.0]	646	462	418	331	5,280
(3600.0, 5400.0]	327	186	250	182	3,845
(5400.0, 7200.0]	73	41	78	52	1,015
(7200.0, 9000.0]	26	8	15	15	236

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	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	NY_	Y1Y	YNN
(394023.5, 472828.2]	0	1	1	2
(472828.2, 551632.9]	0	0	2	4
(630437.6, 709242.3]	0	0	1	0
(709242.3, 788047.0]	0	0	0	6
FICA: Social security retirement payroll deduction				
Universe: All persons				
(-55,449, 5544.9]	14,080	38,087	12,928	8,678
(5544.9, 11089.8]	821	521	979	661
(11089.8, 16634.7]	98	99	209	123
(16634.7, 22179.6]	23	29	85	19
(22179.6, 27724.5]	6	5	21	9
(27724.5, 33269.4]	5	4	13	5
(33269.4, 38814.3]	0	0	4	0
(38814.3, 44359.2]	1	0	2	1
(44359.2, 49904.1]	1	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	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
(19727.5, 45686.0]	20	37	63	54
(45686.0, 71644.5]	6	3	15	6
(71644.5, 97603.0]	0	0	2	6
(97603.0, 123561.5]	0	1	4	0
(123561.5, 149320.0]	0	0	0	0
(149320.0, 175478.5]	0	0	0	0
(175478.5, 201437.0]	0	0	0	0
(201437.0, 227395.5]	0	0	0	0
(227395.5, 253354.0]	0	0	0	1
<b>STATETAX_B: State income tax liability, before credits</b>				
Universe: Tax unit head or dependent filer				
(-253,354, 253354.4]	15,017	38,718	14,185	9,458
				79,632

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

Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NNY	NY_	Y1Y
(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)

```

1 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 = "116 /usr/local/texlive/2024/bin/x86_64-linux"
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, dep_attrs)
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 import os
1 import pandas as pd
2 import pyarrow
3
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_prokdir = "../../../../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_prokdir)
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'],
63                           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,
78                     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 72 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/ppub20enc-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 56 create_dir(data_dir)
29 create_dir(info_dir)
30 create_dir(feat_dir)
31 56 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     79 score_func = partial(mutual_info_classif, discrete_features=
39         discrete_feat_idx)
40     52 feat_selector = SelectKBest(score_func, k=sel_num)
41     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']
46     df_scores["Support"] = feat_selector.get_support()
47     df_scores["F Score"] = feat_selector.scores_
48     df_scores["P Value"] = feat_selector.pvalues_

```

```
49     df_selfeat = df_scores[df_scores['Support']].drop('Support', axis=1).
50         reset_index(drop=True)
50     df_seldata = df_indata[df_selfeat['Attribute']].join(df_indata['class'
51         ])
51
52     minmax = df_seldata.loc[:, df_seldata.columns != 'class'].agg(['min','
53         max']).values.tolist()
53     df_selfeat['Min'] = minmax[0]
54     df_selfeat['Max'] = minmax[1]
55     del minmax
56
57     return df_seldata, df_selfeat, df_scores
58
59 # Implementation
60 df_indata = pd.read_csv(data_filepath)
61 df_info = pd.read_csv(info_filepath)
62
63 print(f"\n{df_indata.head()}\n")
64 print(f"{df_info.head()}\n")
65
66 for sel_num in sel_num_ls:
67
68     # Univariate feature selection
69     df_seldata, df_selfeat, df_scores = feat_select(df_indata=df_indata,
70             df_info=df_info, sel_num=sel_num)
71
71     # Display results (selected features)
72     print(f"Select {sel_num} features:\n")
73     print(f"{df_selfeat}\n")
74
75     # Train-test split
76     df_seltrain = df_seldata.groupby('class', group_keys=False).apply(
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
85     df_selfeat.to_csv(f"{feat_dir}/fnum{sel_num}.csv", header=True, index=
86                     False)
87     df_scores.to_csv(f"{score_dir}/snum{sel_num}.csv", header=True, index=
88                     False)
89
90     df_selfeat.index = df_selfeat.index + 1
91     df_selinfo = df_selfeat.drop(['F Score', 'P Value'], axis=1)
92     df_selinfo.columns = ['variable', 'type', 'min', 'max']
93     df_selinfo.to_csv(f"{info_dir}/{data_selname}num{sel_num}info.csv",
94                     index_label='id')
95
96     df_seltrain.to_csv(f"{train_dir}/{train_name}num{sel_num}each{
97                         train_eachclass_num}.csv", header=True, index=False)
98     df_seltest.to_csv(f"{test_dir}/{test_name}num{sel_num}exc{
99                         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 70 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      print(f"{df.head()}\n")
52
53      # Export
54      create_dir(dc['outdir'])
55      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  $\tilde{x}^i$ :

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

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,

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

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

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

and  $p_0 = 1$ .

Each  $x_j^i \in \mathbb{R}$  is in an open interval  $(b_{j,q}, b_{j,q+1})$  for some  $0 \leq q \leq p_j$ , 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

$$l_{j,q}^i \stackrel{108}{\in} [-M, b_{j,q} + m_j] + M(1 - \alpha_{j,q}^i)$$

$$l_{j,q}^i \stackrel{147}{\in} [b_{j,q} + m_j, M] - M(1 - \alpha_{j,q}^i)$$

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

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

149 *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:

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

10 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  $0 \leq \beta \leq B - 1$ 46

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

$$\sum_{\beta=0}^{B-1} \gamma_\beta^i = 1$$

$$\gamma_\beta^i \in \{0, 1\}.$$

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

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

misclassified instances.

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

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

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

$$h_\beta \stackrel{134}{\geq} - \sum_{i=1}^N y_{k_0}^i \gamma_\beta^i = 0 - \sum_{i=1}^N y_{k_0}^i \gamma_\beta^i \geq - \sum_{i=1}^N y_k^i \gamma_\beta^i - N z_{\beta,k}$$

and this implies

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

Hence

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

□

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

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

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

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

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

#### 4.2 Selection of Mixed-Type Features

More generally, a training instance  $\tilde{x}^i \in \mathbb{R}^{\tilde{d}}$  has a mixed-type component  $\tilde{x}_j^i \in \mathbb{R}$  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

$$S_\beta = \left| \prod_{j \in \mathcal{C}_{\text{cont}}} \sum_{q=0}^{p_j} \beta_{j,q} [b_{j,q}, b_{j,q+1}] \times \prod_{j \in \mathcal{C}_{\text{cat}}} \{u_j\} \right|^{127}$$

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:

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

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

$$\sum_{\beta=0}^{B-1} \gamma_\beta^i = 1,$$

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

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

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:

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

A continuous feature  $\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}$  is deemed significant when

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

and for an original categorical feature  $j \in \tilde{\mathcal{C}}_{\text{cat}}$  corresponding to  $j \in \mathcal{C}_{\text{cat}}$  a new group label  $v_{j, x^i}$  is nonconstant across all training instances  $x^i$ .

The final selection model is proposed:

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

$$\begin{aligned}
& \sum_{j \in \mathcal{C}_{\text{cont}}} \left[ \prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] \left[ \sum_{q=0}^{p_j} q \alpha_{j,q}^i \right] \\
& + \sum_{j \in \mathcal{C}_{\text{cat}}} \left[ \prod_{0 \leq j_0 < j} (p_{j_0} + 1) \right] v_{j,x_j^i} \\
& - \sum_{\beta=0}^{B-1} \beta \gamma_{\beta}^i = 0, \\
& \sum_{q=0}^{p_j} \alpha_{j,q}^i = 1, \quad \quad \quad \textcolor{red}{j} \in \mathcal{C}_{\text{cont}}, \\
& v_{j,x_j^i} + M f_j \geq 0, \quad \quad \quad \textcolor{red}{j} \in \mathcal{C}_{\text{cat}}, \\
& v_{j,x_j^i} - M f_j \leq 0, \quad \quad \quad j \in \mathcal{C}_{\text{cat}}, \\
& \sum_{(j,\tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}} c_{j,\tilde{j}} + \sum_{j \in \mathcal{C}_{\text{cat}}} f_j \leq d, \\
& \sum_{\beta=0}^{B-1} \gamma_{\beta}^i = 1, \\
& h_{\beta} + \sum_{i=1}^N y_k^i \gamma_{\beta}^i + N z_{\beta,k} \stackrel{\textcolor{brown}{10}}{\geq} 0, \\
& \sum_{k=0}^n z_{\beta,k} = n, \\
& l_{j,q}^i, r_{j,q}^i, b_{j,q} \in \mathbb{R}, \quad \quad \quad j \in \mathcal{C}_{\text{cont}}, \\
& h_{\beta} \in \mathbb{R}, \\
& c_{j,\tilde{j}} \stackrel{\textcolor{red}{37}}{\in} \{0, 1\}, \quad \quad \quad (j, \tilde{j}) \in \mathcal{C}_{\text{cont}} \times \tilde{\mathcal{C}}_{\text{cont}}, \\
& \alpha_{j,q}^i \in \{0, 1\}, \quad \quad \quad j \in \mathcal{C}_{\text{cont}}, \\
& f_j \in \{0, 1\}, \quad \quad \quad j \in \mathcal{C}_{\text{cat}}, \\
& v_{j,x_j^i} \in \{0, 1, \dots, p_j\}, \quad \quad \quad j \in \mathcal{C}_{\text{cat}}, \\
& \alpha_{j,q}^i, \gamma_{\beta}^i, z_{\beta,k} \in \{0, 1\}.
\end{aligned}$$

### 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
cplex.intsollim	MIP solution number limit
cplex.tilim	Time limit per optimizer call (in seconds)
cplex.threads	<sup>14</sup> Parallel threads (default: 0 implying up to 32 threads)
cplex.workmem	Working memory before compression and swap (in MB) (default: 2048)
cplex.trelim	Uncompressed tree limit (in MB) (default: $10^{75}$ )
cplex.nodefileind	<sup>14</sup> Node storage file switch <ul style="list-style-type: none"> <li>0: No node file</li> <li>1: Node file in memory and compressed (default)</li> <li>2: Node file on disk</li> <li>3: Node file on disk and compressed</li> </ul>
cplex.status	Solution status code <ul style="list-style-type: none"> <li>1: Optimal for simplex and barrier methods</li> </ul>

Table 4.1: Relevant CPLEX parameters (continued)

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

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

Code 4.1: Main OPL model

```

1  ****
2  * UPL 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
72     0..mp[j]};
73
74 tuple CatPairType { // index for categorical group
75     int j;
76     int l;
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    // Input/variable filenames
101    var infilename = "input/seltrain20num3each20.csv";    // input filename
102    var varfilename = "input/selproc20num3co3ca3cutinfo.csv"; // variable
103        filename (6 columns)
104
105    // Prefix of all output files
106    var prefixout = "output/" + ftime + "-";
107    prefixout += infilename.split("/")[1].split(".")[0] + "-";

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)
116    var limit = 1;    // whether customize performance settings (1 =
117        customize / 0 = none)
118    var perf = 1;    // whether set limits (1 = limit / 0 = none)
119
120    // Custom time limit parameter
121    if (timelimit == 1)
122        var acctimelimmin = 24*60; // accumulated time limit (in minutes)
123
124    // Cplex limit parameters (excluding time limit)
125    if (limit == 1) {
126        var intsollim = 1; // MIP solution number limit (in each iteration)
127    }
128
129    // Cplex performance parameters
130    if (perf == 1) {
131        var threads = 0; // parallel threads (default: 0 = at most 32
132            threads)
133        var workmemgb = 2; // working memory before compression and swap (
134            in GB) (default: 2 GB) (only marginally improved efficiency)

```

```

131      var trelimgb = 200; // 14 uncompressed tree memory limit (in GB) (
132          default: around 1e+72 GB)
133
134      /* Node storage file switch
135      * 0 = No node file
136      * 1 = Node file in memory and compressed (default)
137      * 2 = Node file on disk
138      * 3 = Node file on disk and compressed
139      */
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      // Postfixes
153      var cpostfixname = "mfullaltseltol-" + thisOplModel.mseltol; // common
154          postfix name
155      if (timelimit == 1)
156          cpostfixname += "-t-" + acctimelimmin + ".csv";
157      else
158          cpostfixname += ".csv";
159      var postfixerror = "-" + cpostfixname; // postfix of error file
160      var postfixout = "-pcont-" + pcont0 + "-" + cpostfixname; // postfix of
161          all other output files
162
163      // Output filenames
164      var outererrorname = prefixout + "export-error" + postfixerror;

```

```

162     var outinstancename = prefixout + "export-predict-instance" +
163         postfixout;
164     var outcutcontname = prefixout + "export-cutcont-full" + postfixout;
165     var outcutcatname = prefixout + "export-cutcat-full" + postfixout;
166     // The existence of region is not checked here
167     // In fact, it can be check through enumeration of certain binary
168     // representations
169     var outregionname = prefixout + "export-predict-region" + postfixout;
170     var outselvarintname = prefixout + "export-select-var-int" + postfixout
171         ; // selected variables (integer)
172     var outselvarstrname = prefixout + "export-select-var-str" + postfixout
173         ; // selected variables (string)
174
175     // Engine log (initialized)
176     var logfilename = "log/" + ftime + "-engine-" + cpostfixname.split(".")
177         [0] + ".log";
178     var outlog = new IloOplOutputFile(logfilename);
179
180     // OPL
181     var source = new IloOplModelSource("p-mixed-cuts-alt-seltol.mod");
182     var cplex = new IloCplex();
183     var def = new IloOplModelDefinition(source);
184     var opl = new IloOplModel(def,cplex);
185     var data = new IloOplDataElements();
186
187     data.dimold = thisOplModel.mdimold;
188     data.dimcontold = thisOplModel.mdimcontold;
189     data.dim = thisOplModel.mdim;
190     data.dimcont = thisOplModel.mdimcont;
191     //data.dimcat = thisOplModel.mdimcat;
192     data.N = thisOplModel.mN;
193     data.n = thisOplModel.mn;
194     data.xcontold = thisOplModel.mxcontold;
195     data.xcat = thisOplModel.mxcat;
196     data.y = thisOplModel.my;
197
198 
```

```

193 var pred = thisOplModel.mpred; // set of predicted labels
194
195 data.seltol = thisOplModel.mseltol;
196 data.selcont = thisOplModel.mselcont;
197 data.exccont = thisOplModel.mexccont;
198
199 data.m = thisOplModel.mm;
200 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.max1(Opl.abs(Opl.intValue(myitem[3])), Opl.abs(Opl.intValue(myitem[4]))));

```

```

228         M0cont = Opl.max1(M0cont, curMcont);
229     }
230     else {
231         data.p[j-data.exccont] = Opl.intValue(myitem[5]);
232         data.maxlab[j-data.exccont] = Opl.intValue(myitem[4]);
233         data.M[j-data.exccont] = 1 + Opl.intValue(myitem[5]);
234     }
235 }
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)

```

```

263     cplex.trelim = trelim; // uncompressed tree memory limit (in MB)
264     cplex.nodefileind = nodefileind; // node storage file switch
265 }
266
267 // Initialization
268 var status = -9; // solution status code (initialized)
269 var iter = 0; // iteration
270 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

```

```

297      */
298
299      // In the case when the previous status is not one of the above
300      if (timelimit == 1)    // time limit for each call to optimizer (in
301          seconds)
302          cplex.tilim = acctimelim - acctime;
303
304      var start = new Date(); // begin a timer
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)

```

```

326     var outererror = new IloOplOutputFile(outerrorname, true);
327     var outinstance = new IloOplOutputFile(outinstancename, true);
328     var outcutcont = new IloOplOutputFile(outcutcontname, true);
329     var outcutcat = new IloOplOutputFile(outcutcatname, true);
330     var outregion = new IloOplOutputFile(outregionname, true);
331     var outselvarint = new IloOplOutputFile(outselvarintname, true);

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

333
334     // outererror
335     if (!outererror.exists) {
336         outererror.write("iter,");
337         for (var j=1; j<=data.dim; j++)
338             outererror.write("p", j, ",");
339         outererror.write("error,accuracy,ms,acctmin,status,lberr,
340                         relgap");
341     }
342     outererror.write("\n", iter, ",");
343     for (var j=1; j<=data.dim; j++)
344         outererror.write(data.p[j], ",");
345     outererror.write(error, "", accuracy, ",");
346     outererror.write(solvetime, "", acctime/60, ",");
347     outererror.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;
366
367             for (var k=0; k<=data.n; k++) {
368                 var num = 0;
369                 for (var i=1; i<=data.N; i++)
370                     num += (data.y[i] == k)*opl.g.solutionValue[i][b];
371
372                 if (num == maxnum)
373                     lset.add(k);
374                 else if (num > maxnum) {
375                     maxnum = num;
376                     lset.clear();
377                     lset.add(k);
378                 }
379             }
380             pred.add(b, lset);
381         }
382
383         // outinstance
384         if (!outinstance.exists)
385             outinstance.write("iter,id,class,region,predict");
386
387         for (var i=1; i<=data.N; i++) {
388             outinstance.write("\n", iter, ",", i, ",", data.y[i], ",");
389             for (var b=0; b<opl.B; b++)
390                 if (opl.g.solutionValue[i][b] == 1) { // occur only once
391                     outinstance.write(b, ",");
392                     outinstance.write(pred.get(b).label);
393                     break; // terminate the loop
394                 }
395         }

```

```

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; // itermminate the loop
423             }
424         outregion.write(s, ",");
425         outregion.write(pred.get(b).label);
426     }

```

```

427
428     // outselvarint
429     if (!outselvarint.exists)
430         outselvarint.write("iter,j,jold,mselect,type"); // mselect =
431         model select (not actual)
432     for (var j=1; j<=data.dimcont; j++) { // selected continuous
433         features
434         outselvarint.write("\n", iter, ",", j, ",");
435         var seljold = -1;
436         for (var jold=1; jold<=data.dimcontold; jold++)
437             // Determine which old continuous feature is selected
438             if (opl.ccont.solutionValue[j][jold] == 1) {
439                 seljold = jold;
440                 break; // terminate the loop
441             }
442         outselvarint.write(seljold, ",");
443         outselvarint.write("1,"); // Based on model, all new cont
444         features are selected
445         outselvarint.write("cont");
446     }
447     for (var j=data.dimcont+1; j<=data.dim; j++) { // categorical
448         feature
449         outselvarint.write("\n", iter, ",", j, ",", j+data.exccont,
450             ",");
451         if (opl.f.solutionValue[j] == 1) // selected categorical
452             feature (model)
453             outselvarint.write("1,");
454             else // unselected categorical feature (model)
455             outselvarint.write("0,");
456             outselvarint.write("cat");
457     }
458
459     // outselvarstr
460     if (!outselvarstr.exists)
461         outselvarstr.write("iter,jold,jnew,aselect,type,variable");
462         // aselect = actual select

```

```

456     var varinfile = new IloOplInputFile(varfilename); // variable
        info
457     varinfile.readline(); // skip a header
458     var numselcont = 0; // initialized number of actually selected
        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;

```

```

482         }
483     }
484 }
485 outselvarstr.write(aselect, ",");
486 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     }
516     outselvarstr.write(aselect, ",");
517     if (aselect == 1) { // actually selected categorical feature

```

```

511         // Scripting logs 2 (categorical)
512         write("\t", myitem[1], " (Categorical)\n");
513         numselcat += 1;
514     }
515     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 outererror.close();
528 outinstance.close();
529 outcutcont.close();
530 outcutcat.close();
531 outregion.close();
532 outselvarint.close();
533 outselvarstr.close();
534 }
23 else
535 writeln("No solution");
536
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  * 22 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 ****
114 subject to {
23
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:
132             (sum(jold in DSCONTOLD) xcontold[i][jold]*ccont[j][jold]) - (
133                 sum(q in 0..p[j]) r[<i,j,q>]) <= 0;
134         }
135
136         forall(i in IS, j in DSCONT, q in 0..p[j]) {
137             l[<i,j,q>] + M[j]*a[<i,j,q>] 43 >= 0;
138             l[<i,j,q>] - M[j]*a[<i,j,q>] 59 <= 0;
139             l[<i,j,q>] - bc[<j,q>] + M[j]*a[<i,j,q>] 10 <= M[j] + m[j];
140             l[<i,j,q>] - bc[<j,q>] - M[j]*a[<i,j,q>] 10 >= -M[j] + m[j];
141             r[<i,j,q>] + M[j]*a[<i,j,q>] 59 >= 0;
142             r[<i,j,q>] - M[j]*a[<i,j,q>] <= 0;
143             r[<i,j,q>] - bc[<j,q+1>] + M[j]*a[<i,j,q>] 10 <= M[j] - m[j];
144             r[<i,j,q>] - bc[<j,q+1>] - M[j]*a[<i,j,q>] >= -M[j] - m[j];
145         }
146
147         forall(i in IS)
148             (sum(j in DSCONT) coef[j]*(sum(q in 0..p[j]) q*a[<i,j,q>]) 49 + (sum(
149                 j in DSCAT) coef[j]*v[<j,xcat[i][j]>]) - (sum(b in BS) b*g[i][b]
150                 ]) == 0;
151
152         forall(i in IS, j in DSCONT)
153             pregion:
154                 sum(q in 0..p[j]) a[<i,j,q>] == 1;
155
156         forall(i in IS) {
157             bregion:
158                 sum(b in BS) g[i][b] == 1;
159         }
160
161         forall(b in BS, k in KS)
162             error1:
163                 h[b] + (sum(i in IS) (y[i] == k)*g[i][b]) + N*z[b][k] >= 0;

```

```

160
161     forall(b in BS)
162         error2:
163             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             v[<j,xcat[i][j]>] + 130M[j]*f[j] >= 0;
171         selcat2:
172             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;

```

#### 4.4 Recalculation of Decision Boxes

Some of  $d$  selected 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, the proposed classification model usually assumes that there are up to  $d$  new continuous features ( $|\mathcal{C}_{\text{cont}}| \leq d$ ), but a new continuous feature  $j \in \mathcal{C}_{\text{cont}}$  may turn unselected:  $c_{j,\tilde{j}}^* = 0$  for all  $\tilde{j} \in \tilde{\mathcal{C}}_{\text{cont}}$ . 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.

102 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:

$$\overset{128}{g(\beta)} - g(\beta - 1) = - \sum_{j=1}^{w-1} p_j \prod_{j' \in \Sigma_j} (p_{j'} + 1) + 1 \cdot \prod_{j' \in \Sigma_w} (p_{j'} + 1)$$

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

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) 45

```

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:
17         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
75     Required arguments:
76         dc: dictionary
77
78     Outputs:
79
80         kmax: set of all keys of maximum value
81         vmax: maximum value
82
83     """
84
85     kmax = set()
86     vmax = dc[next(iter(dc))] # value of first key
87
88     for k, v in dc.items():
89         if v > vmax:
90             vmax = v
91             kmax = {k}
92         elif v == vmax:
93

```

```

87         kmax.add(k)
88
89     return kmax, vmax
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
98         Required arguments:
99
100            x: specific value of interest
101            splits: list of real line splits
102            closed: whether intervals are closed on left-side, right-side
103                or neither ('left', 'right', 'neither')
104
105        Outputs:
106            interval index of specific input value
107
108    """
109
110    if closed == 'left': # [_, s), [s, _]
111        for i, s in enumerate(splits):
112            if x < s: return i
113    elif closed == 'neither': # (_, s), (s, _)
114        for s in splits:
115            if x == s:
116                raise Exception(f"Open intervals are chosen but input value
117                    {x} is at split value {s}")
118    closed = 'right' # now safe to be extended to (_, s], (s, _]
119
120    if closed == 'right': # (_, s], (s, _]
121        for i, s in enumerate(splits):
122            if x <= s:
123                return i
124
125    # Last interval
126    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
127         Required arguments:
128             itv: Pandas interval to be rounded
129
130         Optional arguments:
131             37
132                 decimals: number of decimal places to round to (default: 2)
133
134                 extend: whether extend (true) or shrink (default) interval (
135                     default: True)
136
137         Outputs:
138             lpt: left endpoint of rounded interval
139             rpt: right endpoint of rounded interval
140
141     """
142
143     if isinstance(itv, pd._libs.interval.Interval):
144
145         if extend:
146
147             ldirect, rdirect = 'down', 'up'
148
149         else:
150
151             ldirect, rdirect = 'up', 'down'
152
153         if np.isinf(itv.left):
154
155             lpt = itv.left
156
157         else:
158
159             lpt = round_num(itv.left, decimals, ldirect)
160
161
162         if np.isinf(itv.right):
163
164             rpt = itv.right
165
166         else:
167
168             rpt = round_num(itv.right, decimals, rdirect)
169
170
171     return lpt, rpt
172
173
174 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
190     dfn = df.copy(deep=True)
```

```

189     for i in range(len(ndcols),0,-1): # iterate over multilevel column
190         lists with nonduplicate entries
191         ccols = [f for cols in ndcols[0:i] for f in cols]
192         dfn.loc[dfn[ccols].duplicated(), ccols] = pd.NA
193         for col in intcols:
194             dfn[col] = pd.array(dfn[col], dtype=intdtype)
195
196     return dfn

```

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

```

1 import re
2 12 import numpy as np
3 import pandas as pd
4
5 from module.operation.xutil import itvtopts
6
7
8 # Convert set/number in string format to Python set
9 def strtoset(setstr):
10     """
11         Usage: convert set/number in string format to Python set
12         Required arguments:
13             setstr: set/number in string format
14         Outputs: corresponding set
15     """
16
17     elems = re.findall(r'^{}; \s+', setstr)
18     numset = set(map(int, elems))
19
20     return numset
21
22
23 # Convert set to string
24 def settostr(st, sep=',', left='{', right='}'):
25     """

```

```

26     Usage: convert set to string
27     Required arguments:
28         st: set
29     Optional arguments:
30         sep: separator (default: ',')
31         left: left symbol (default: '{')
32         right: right symbol (default: '}')
33     Outputs: string representing given set
34     ...
35
36     stre = sep.join([str(e) for e in st])
37
38     return f"{left}{stre}{right}"
39
40
41 # Convert Pandas interval to string
42 def itvtostr(itv, decimals=2, extend=True):
43     ...
44     Usage: convert Pandas interval to string
45     Required arguments:
46         itv: Pandas interval
47     Optional arguments:
48         37    decimals: number of decimal places to round to (default: 2)
49         extend: whether extend (true) or shrink (default) interval (
50             default: True)
51     Outputs: string interval
52     ...
53
54     lpt, rpt = itvopts(itv, decimals, extend)
55     l = f"{lpt:.{decimals}f}"
56     r = f"{rpt:.{decimals}f}"
57
58     if itv.closed == 'neither': return f"({l}, {r})"
59     elif itv.closed == 'left': return f"[{l}, {r})"
60     elif itv.closed == 'right': return f"({l}, {r}]"
61     else: return f"[{l}, {r}]"

```

```
61
62
63 # Describe Pandas interval in text format
64 def itvtodesc(itv, decimals=2, extend=True):
65     """
66         Usage: describe Pandas interval in text format
67         Required arguments:
68             itv: Pandas interval
69         Optional arguments:
70             37         decimals: number of decimal places to round to (default: 2)
71             extend: whether extend (true) or shrink (default) interval (
72                 default: True)
73         Outputs: description of interval in text format
74     """
75
76     lpt, rpt = itvtopts(itv, decimals, extend)
77     l = f"{lpt:.{decimals}f}"
78     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, bnperv, 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            bnperv: 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 = bnperv
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 -= pcuto[j]*pncumx[idxn[j]]
26            bn += pncumx[idxn[jmax]]
27            break
28    return bn
29
30
31 # Calculate corresponding decision regions (helper)
32 def hcalregs(B0, idxn, pcuto, pocum, pncumx):

```

```

33      """
34      Usage: calculate corresponding decision regions (helper)
35      Required arguments:
36          BO: total number of old box regions
37          idxn: new feature indexes
38          pcuto: 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
45      bns = [0] # list of corresponding box regions (region 0)
46      for bo in range(1, BO):
47          bnperv = bns[-1]
48          bn = hcalbn(bo, bnperv, idxn, pcuto, pocum, pncumx)
49          bns.append(bn)
50
51      return bns
52
53 # Calculate new corresponding decision regions (main)
54 def calregs(pcuto, sidx, pdtype=np.int16, idtype=np.int16, rdtype=np.int16
55     ):
56     """
57     Usage: calculate new corresponding decision regions (main)
58     Required arguments:
59         pcuto: 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      # Typecasting
68      pcuto = np.array(pcuto, dtype=pdtype)
69      sidx = np.array(sidx, dtype=idtype)
70
71      # Basic calculation
72      dimo = pcuto.size # old dimension
73      dimn = sidx.size # new dimension
74      pcutn = pcuto[sidx] # new cut numbers
75      B0 = np.prod(pcuto+1).astype(rdtype) # number of old regions
76      BN = np.prod(pcutn+1).astype(rdtype) # number of new regions
77
78      # New feature indexes
79      idxn = np.full(dimo, -1, dtype=idtype)
80      idxn[sidx] = np.arange(dimm, dtype=idtype)
81      idxn[idxn < 0] = np.arange(dimm, dimo, dtype=idtype)
82
83      # Cumulative number of box regions
84      pocum = np.cumprod(np.append([1], pcuto[0:-1]+1), dtype=rdtype) # old
85      pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=rdtype) # new
86      pncumx = np.concatenate((pncum, np.zeros(dimo-dimm, dtype=rdtype))) #
87          new and extended
88
89      # New corresponding regions (helper function called)
90      bns = np.array(hcalregs(B0, idxn, pcuto, pocum, pncumx), dtype=rdtype)
91
92      # Output
93      return bns
94
95
96  """
97  print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0],
98      calregs(pcuto, sidx)))
99  print('pcuto: {0}\nsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1],
100     calregs(pcuto, sidx)))

```

```

99 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[0,
1], calregs(pcuto, sidx)))
100 print('pcuto: {0}\nnsidx: {1}\nbns: {2}\n'.format(pcuto:=[3, 4], sidx:=[1,
0], calregs(pcuto, sidx)))
101 """

```

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(itsel) # iterator of selected string variables across all
13        iterations
14     tsels = dict() # selected variables and given number of cuts
15
16     citer = -1 # current iteration
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                     }

```

```

27         tsels[citer]['variables'].append(csrow.variable)
28         tsels[citer]['types'].append(csrow.type)
29         tsels[citer]['js'].append(csrow.jnew)
30         tsels[citer]['ps'].append(pculo[csrow.jnew-1])
31         csrow = next(itsel) # update DataFrame iterator
32     except StopIteration:
33         break
34
35     return tsels

```

Code 4.7: Cuts or split values (module/model/findcuts.py)<sup>106</sup>

```

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
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
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87
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90
91
92
93
94
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102
103
104
105
106

```

```

19     ccontrow = next(itcont) # iterator of full continuous cuts across all
20         iterations
21     ccatrow = next(itcat) # iterator of full categorical cuts across all
22         iterations
23     tcuts = dict() # cuts and groups along all selected features
24
25     for citer, sel in tsels.items(): # cuts across all selected features
26         tcuts[citer] = dict()
27         for ind, j in enumerate(sel['js']):
28             tcuts[citer][j] = {
29                 'variable': tsels[citer]['variables'][ind],
30                 'type': tsels[citer]['types'][ind],
31                 'cuts': list(),
32                 'groups': dict()
33             }
34
35     # Cuts
36     while ccontrow.iter < citer: # previous iteration may select no
37         continuous feature
38         ccontrow = next(itcont)
39     while ccatrow.iter < citer: # previous iteration may select no
40         categorical feature
41         ccatrow = next(itcat)
42     for jcur in sorted(sel['js']): # numerically sorted features
43         selected
44         cuts = tcuts[citer][jcur]['cuts'] # list of cuts along specific
45         selected feature
46         try: # iterate over full continuous cuts
47             while ccontrow.iter == citer:
48                 if ccontrow.j > jcur: # seek no more than current
49                     feature
50                     break
51                 else:
52                     if ccontrow.j == jcur: # at current selected feature
53                         cuts.append(ccontrow.bc) # continuous feature
54                         seen

```

```

47             ccontrow = next(itcont) # update DataFrame iterator
48         except StopIteration:
49             pass
50         try: # iterate over full categorical cuts
51             while ccatrow.iter == citer:
52                 if ccatrow.j > jcur: # seek no more than current feature
53                     break
54                 else:
55                     if ccatrow.j == jcur: # at current selected feature
56                         cuts.append(ccatrow.v) # categorical feature seen
57                     ccatrow = next(itcat) # update DataFrame iterator
58             except StopIteration:
59                 pass
60
61         # Groups
62         pcutdc = dict(zip(tsels[citer]['js'], tsels[citer]['ps'])) # cut
63             numbers along selected features
64         for j, info in tcuts[citer].items():
65             pnum = pcutdc[j] # number of cuts on current selected feature
66             cuts = info['cuts']
67             if info['type'] == 'cont': # continuous feature
68                 excuts = [-np.inf] + cuts + [np.inf]
69                 intvs = pd.arrays.IntervalArray.from_breaks(
70                     breaks=excuts,
71                     copy=False, # default: False
72                     closed=intvclosed, # types of Pandas interval sides
73                     dtype=pd.IntervalDtype(subtype=intvsubtype)) # types of
74                         Pandas interval bounds
75             )
76             info['groups'] = {gr: intvs[gr] for gr in range(pnum+1)}
77         else: # categorical feature
78             info['groups'] = {gr: set() for gr in range(pnum+1)}
79             for val, gr in enumerate(cuts):
80                 info['groups'][gr].add(val) # categorical value in cut/
81                     group
82
83

```

```
80     return tcuts
```

Code 4.8: True decision regions (module/model/findtregs.py)

```

1 12 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
17             df: training dataset including target variable (DataFrame, not
18                 iterator)
19         Optional arguments:
20             pdtype: NumPy data type of cut number (default: np.int16)
21         Outputs:
22             ttregs: dictionary of new true decision regions and their
23                 predicted classes
24
25     """
26     ttregs = dict() # new true regions with predicted classes (truly
27                     correct)
28     classes = df['class'].unique() # all possible classes
29
30     for citer in tsels.keys():
31         regs = pd.Series([0]*len(df))
32         js = tsels[citer]['js']

```

```

27     pcutn = np.array(tsels[citer]['ps'], dtype=pdtype) # new cut
28         numbers
29     pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=pdtype) #
30         cumulative number of new box regions
31     BN = np.prod(pcutn+1) # number of new regions
32
33     # Convert base representation of decision region to base 10
34     for ind, j in enumerate(jc):
35         info = tcuts[citer][j]
36         attr = info['variable']
37         cuts = info['cuts']
38         if info['type'] == 'cont': # continuous feature
39             regs = regs + pncum[ind]*df[attr].apply(lambda x: itvpos(x,
40                                         cuts))
41         else: # categorical feature
42             regs = regs + pncum[ind]*pd.Series([cuts[x] for x in df[attr]
43                                         ]])
44
45     # Find predicted classes in decision regions
46     ttregs[citer] = {
47         b: {
48             'classes': set(), # true predicted class set
49             'correct': 0, # number of instances correctly predicted
50             'ninst': 0, # number of training instances (total)
51             'ncinst': {n: 0 for n in range(len(classes))} # number of
52                 training instances in targets
53         } for b in range(BN)
54     }
55     for i in range(len(df)):
56         ttregs[citer][regs[i]]['ninst'] += 1 # instance in region
57         ttregs[citer][regs[i]]['ncinst'][df['class'][i]] += 1 #
58             instance of specific target in region
59     for b in range(BN):
60         kmax, vmax = max_dictval(ttregs[citer][b]['ncinst']) # true
61             majority voting

```

```

55         ttregs[citer][b]['classes'] = kmax # all classes that have
56             maximum number of instances
56         ttregs[citer][b]['correct'] = vmax # maximum number of
57             instances
57
58     return ttregs

```

Code 4.9: CPLEX decision regions (module/model/findcregs.py)<sup>109</sup>

```

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 findcregs(tsels, itpred, pcuto, idtype=np.int16, pdtype=np.int16):
9     """
10         Usage: calculate new cplex decision regions and predictions (per
11             file)
12         Required arguments:
13             tsels: dictionary of selected variables and given number of
14                 cuts
15             itpred: individual result of cplex prediction (DataFrame
16                 iterator)
17             pcuto: old cut numbers
18         Optional arguments:
19             pdtype: NumPy data type of cut number (default: np.int16)
20             idtype: NumPy data type of index (default: np.int16)
21         Outputs:
22             tcregs: dictionary of new cplex decision regions and their
23                 predicted classes
24
25     """
26     cprow = next(itpred) # iterator of instance predictions across all
27     iterations

```

```

23     tcregs = dict() # new cplex regions with predicted classes (partially
24         correct)
25
26     classes = set() # set all possible classes (collected from training
27         dataset)
28
29     citer = -1 # current iteration
30
31     while True: # reported by cplex as occupied region
32         try:
33             if cprow.iter != citer: # new iteration
34                 citer = cprow.iter
35
36                 if citer in tsels.keys(): # current iteration actually
37                     selects at least one feature
38
39                     keep = True # keep doing in this while loop
40
41                     pcutn = np.array(tsels[citer]['ps'], dtype=pdtype)
42                     sidx = np.array(tsels[citer]['js'], dtype=idtype) - 1 #
43                         index starts at 0
44
45                     BN = np.prod(pcutn+1) # number of new regions
46
47                     bns = calregs(pcutn, sidx) # new corresponding regions
48
49                     tcregs[citer] = {
50                         b: {
51                             'lclasses': list(), # list of cplex predicted
52                                 class set
53
54                             'nlcinst': list() # list of instance number in
55                                 corresponding cplex class set
56
57                         } for b in range(BN)
58
59                     }
60
61             else: # current iteration selects no feature
62                 keep = False # update iterator and go to the next while
63                     loop
64
65             if keep and cprow.iter == citer: # every record in iteration
66                 that selects feature
67
68                 creg = tcregs[citer][bns[cprow.region]] # new cplex region
69
70                 pset = strtoset(cprow.predict) # current set of classes
71
72                     predicted by cplex

```

```

49         classes = classes.union(pset) # add to set of all possible
50             classes
51
52             try: # current set of predicted classes already exists
53                 creg['nlcinst'][creg['lclasses'].index(pset)] += 1
54
55             except ValueError: # new set of predicted classes
56                 creg['lclasses'].append(pset)
57                 creg['nlcinst'].append(1)
58
59             cprox = next(itpred) # update DataFrame iterator
60
61             except StopIteration:
62                 break
63
64
65     for cregs in tcregs.values(): # reported by cplex as unoccupied region
66         for creg in cregs.values():
67             if not creg['lclasses']:
68                 creg['lclasses'] = [classes] # predict only one of the
69                     entire set
70
71             nlcinst = [0] # no instance reported by cplex in the rest of
72                         new regions
73
74
75     return tcregs

```

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
11        Outputs:
12            tcorr: true number of correctly classified instances per region
13            ccorr: recalculated cplex number of correctly classified
14                instances per region

```

```

11     """
12
13     tcorr = dict() # true correctness
14     ccorr = dict() # cplex correctness
15     for citer, tregs in ttregs.items(): # true classification
16         tcorr[citer] = {
17             'correct': 0,
18             'detail': {b: tregs[b]['correct'] for b in tregs.keys()}
19         }
20         tcorr[citer]['correct'] = sum(tcorr[citer]['detail'].values())
21     for citer, cregs in tcregs.items(): # cplex classification
22         ccorr[citer] = {
23             'correct': 0,
24             'detail': {b: 0 for b in cregs.keys()}
25         }
26         for b in cregs.keys():
27             for soc in tcregs[citer][b]['lclasses']:
28                 ccorr[citer]['detail'][b] = max([ttregs[citer][b]['ncinst'][c] for c in soc])
29         ccorr[citer]['correct'] = sum(ccorr[citer]['detail'].values())
30
31     return tcorr, ccorr

```

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

```

1 import csv
2 import re
3 114 import pandas as pd
4
5 from module.operation.xutil import *
6 from module.operation.typecast import *
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 datdir = "../../Projects/Box Classifiers/alternative/input" # directory
30           of training instances (cplex inputs)
31 indir = "../../Projects/Box Classifiers/alternative/output" # main
32           input directory (cplex results)
33 datfile = f"{data}.csv" # training dataset with target variable
34 datpredfile = f"{inprefix}predict-instance-pcont-3{inpostfix}.csv" #
35           individual result of cplex prediction
36 inerrfile = f"{inprefix}error{inpostfix}.csv" # classification errors and
37           performance metrics
38 inselinfile = f"{inprefix}select-var-str-pcont-3{inpostfix}.csv" # selected
39           string variables
40 incutcontfile = f"{inprefix}cutcont-full-pcont-3{inpostfix}.csv" #
41           continuous cuts
42 incutcatfile = f"{inprefix}cutcat-full-pcont-3{inpostfix}.csv" #
43           categorical cuts
44
45 # Optional inputs
46 if issreport: # reports of feature selection must be written
47     metadir = "../../Data/Encoded/metadata" # metadata directory

```

```

40     metafile = "meta-indep-pppub20enc.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     outerepperfile = 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
            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
            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
        and performance metrics
67     dfs = pd.read_csv(f"{indir}/{inselfile}") # selected string variables
68     dfcont = pd.read_csv(f"{indir}/{icutcontfile}") # full continuous cuts

```

```

69 dfcat = pd.read_csv(f"{indir}/{incutcatfile}") # full categorical cuts
70 df = pd.read_csv(f"{datadir}/{datfile}") # training dataset including
    target variable
71 dfp = pd.read_csv(f"{indir}/{datpredfile}") # individual result of cplex
    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, pculo) # selected variables
81 tcuts = findcuts(tsels, itcont, itcat) # cuts along all selected features
82 ttregs = findtregs(tsels, tcuts, df) # new true regions and predicted
    classes
83 tcregs = findcregs(tsels, itpred, pculo) # new cplex regions and predicted
    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()],
        # true accuracies
90     'caccuracy': [info['correct']*100/len(df) for info in ccorr.values()],
        # recalculated cplex accuracies
91     'terror': [len(df) - info['correct'] for info in tcorr.values()], #
        true errors
92     'cerror': [len(df) - info['correct'] for info in ccorr.values()] #
        recalculated cplex errors
93 })
94 dfen = pd.merge(dfen, dfe, how='outer')
95 dfen.rename(columns = {
96     'error': 'rror', # reported cplex errors

```

```

97     'accuracy': 'raccuracy' # reported cplex accuracies
98 }, inplace=True)
99 cols = dfen.columns.tolist()
100 new_cols = cols[0:1] + cols[5:5+len(pcuto)] + cols[1:3] + cols[-6:-5] +
101     cols[3:5] + cols[-7:-6] + cols[-5:]
102 dfen = dfen[new_cols] # rearranged columns
103 dfen['ms'] = dfen['ms']/60000 # convert milliseconds to minutes
104 dfen = dfen.rename(columns={'ms':'minute'})
105
106 # Display performance results
107 print(f"\n{dfen}\n")
108
109 # Examples
110 if isexample:
111     iters = [1, 2, 15]
112     for citer in iters:
113         try:
114             print(f"Selected features (iteration {citer})\n{tsels[citer]}\n")
115             print(f"Cuts (iteration {citer})\n{tcuts[citer]}\n")
116             print(f"True decision regions (iteration {citer})\n{ttrgns[
117                 citer]}\n")
118             print(f"Cplex decision regions (iteration {citer})\n{tcregs[
119                 citer]}\n")
120             print(f"True correctness (iteration {citer})\n{tcorr[citer]}\n")
121
122             print(f"Cplex correctness (iteration {citer})\n{ccorr[citer]}\n")
123         except KeyError:
124             print(f"Iteration {citer} selects no features\n")
125
126 # Export non-edited information
127 copy(f"{indir}/{incutcontfile}", f"{outdir}/{outcutcontfile}") #
128     continuous cuts
129 copy(f"{indir}/{incutcatfile}", f"{outdir}/{outcutcatfile}") # categorical
130     cuts

```

```

125
126 # Export performance results (accuracy/error/time)
127 dfen.to_csv(f"{outdir}/{outperffile}", float_format=".2f", header=True,
128             index=False)
129
130 # Export selected variables, cuts and groups
131 with open(f"{outdir}/{outselfile}", 'w', newline='') as file:36
132     writer = csv.DictWriter(
133         file,
134         fieldnames = [
135             'iter', 'jfin', 'j', 'var', 'type',
136             'p', 'cuts', 'groups'
137         ]
138     )
139     writer.writeheader()
140     for citer, info in tsels.items():
141         cuts = [[round(cut, 2) for cut in tcuts[citer][j]['cuts']] for j in
142                 info['js']]
143         groups = list()
144         for ind, j in enumerate(info['js']):
145             if info['types'][ind] == 'cont': # continuous feature
146                 jgrs = dict()
147                 for gr, member in tcuts[citer][j]['groups'].items():
148                     jgrs[gr] = itvtostr(member)
149                 groups.append(jgrs)
150             else: # categorical feature
151                 groups.append(tcuts[citer][j]['groups'])
152     dfstmp = pd.DataFrame({
153         'iter': citer,
154         'jfin': range(1, len(info['js'])+1), # 1, 2, ...
155         'j': info['js'], # j in cplex model
156         'variable': info['variables'],
157         'type': info['types'],
158         'p': info['ps'],
159         'cuts': cuts,
160         'groups': groups

```

```

159     })
160     dfstmp.to_csv(f"{outdir}/{outselfile}", mode='a', header=False, index=
161         False)
162
163 # Export predicted classes and number of instances in all decision regions
164 with open(f"{outdir}/{outregfile}", 'w', newline='') as file:36
165     writer = csv.DictWriter(
166         file,
167         fieldnames = [
168             'iter', 'reg', 'ninst', 'tpred', 'lrpreds',
169             'tcorr', 'ccorr', 'ncinst'
170         ]
171     )
172     writer.writeheader()
173     for citer, tregs in ttregs.items():
174         for b, treg in tregs.items():
175             # List of predicted classes reported by cplex in string format
176             lrpreds = settostr(map(settostr, tcregs[citer][b]['lclasses']),
177                 left='[', right=']')
178             writer.writerow({
179                 'iter': citer,
180                 'reg': b,
181                 'ninst': treg['ninst'], # number of instances
182                 'tpred': settostr(treg['classes']), # true predicted class
183                 'lrpreds': lrpreds,
184                 'tcorr': tcorr[citer]['detail'][b], # true correctness
185                 'ccorr': ccorr[citer]['detail'][b], # cplex correctness
186                 'ncinst': treg['ncinst'] # targets and number of member
187                     instances
188             })
189 # Export final reports of feature selection (with duplicate/nonduplicate
190     entries) (if specified)

```

```

191 if issreport: # reports of feature selection must be written
192
193     # New labels of selected categorical features (catvdc)
194     metadc = import_dict(jsonPath=f'{metadir}/{metafile}') # metadata after
195         encoding
196     catvars = set() # all selected categorical features (initialized)
197     pattern = r'(^|[\w])(niu)([\w]|$)' # regex to search for niu
198     pattern = re.compile(pattern, re.IGNORECASE)
199     for info in tsels.values():
200         for ind, attr in enumerate(info['variables']):
201             if info['types'][ind] == 'cat':
202                 catvars.add(attr)
203     catvdc = {attr: metadc[attr]['values'] for attr in catvars} # labels of
204         selected categorical features
205     for attr, valdc in catvdc.items():
206         for val, desc in valdc.items():
207             matches = re.search(pattern, desc.replace(',', ' '))
208             if bool(matches): # case-insensitive value label containing niu
209                 try:
210                     catvdc[attr][val] = niudc[attr] # relabel
211                 except KeyError: # new NIU label of current feature is
212                     missing
213                 pass
214
215     # True classification accuracies and performance metrics
216     efields = ['iter', 'taccuracy', 'minute', 'acctmin', 'status']
217
218     # Groups
219     grls = list() # list of all member groups across all features and
220         iterations
221     for citer, scuts in tcuts.items():
222         for j, info in scuts.items(): # cuts along all selected feature
223             vartype = 'Continuous' if info['type']=='cat' else 'Categorical'
224             '
225             if info['type'] == 'cont': # continuous feature (groups not
226                 displayed for convenience)

```

```

221         for gr, member in info['groups'].items():
222             dc = {
223                 'iter': citer,
224                 'j': j, 'variable': info['variable'],
225                 'type': 'Continuous',
226                 'label': metadc[info['variable']]['label'],
227                 'group': gr,
228                 'member': itvtostr(member),
229                 'desc': itvtodesc(member, decimals=0, extend=False).
230                         capitalize()
231             }
232             grls.append(dc)
233     else: # categorical feature (groups displayed)
234         for gr, member in info['groups'].items():
235             for elem in member: # all elements in group member
236                 desc = catvdc[info['variable']][str(elem)]
237                 dc = {
238                     'iter': citer,
239                     'j': j, 'variable': info['variable'],
240                     'type': 'Categorical',
241                     'label': metadc[info['variable']]['label'],
242                     'group': gr,
243                     'member': elem,
244                     'desc': desc
245                 }
246                 grls.append(dc)
247
248     dfg = pd.DataFrame(grls) # group dataframe
249
250     # Report dataframe of feature selection with duplicate entries (dfrp)
251     dfsrp = pd.merge(dfen[efields], dfg) # merge two dataframes: error/
252                                         metric and group
253
254     # Report dataframe of feature selection with nonduplicate entries (dfn)
255     dfsrpn = nondup(
256         dfsrp,
257         ndcols=[
```

```

255         ['iter', 'taccuracy', 'minute', 'acctmin', 'status'],
256         ['j', 'variable', 'type', 'label'],
257         ['group']
258     ],
259     intcols=['iter', 'status', 'j', 'group'] # integer columns
260 )
261
262 # Export final reports of feature selection
263 dfsrp.to_csv( # with duplicate entries
264     f"{outdir}/{outsrepwdfile}",
265     25
266     float_format=".2f",
267     header=True, index=False
268 )
269 dfsrpn.to_csv( # with nonduplicate entries
270     f"{outdir}/{outsrepndfile}",
271     25
272     sep=',', na_rep='',
273     float_format=".2f",
274     header=True, index=False
275 )
276 print(f"{dfsrp.head()}\n") # feature selection (with duplicate entries)
277 print(f"{dfsrpn.head()}\n") # feature selection (with nonduplicate entries
278 )
279 # Export final reports of detailed decision regions (with duplicate/
280 # nonduplicate entries) (if specified)
281 if isrreport: # reports of detailed decision regions must be written
282
283     # Export final reports of detailed regions (with duplicate entries)
284     with open(f"{outdir}/{outrrepwdfile}", "w", newline='') as file:
285         writer = csv.DictWriter(
286             file,
287             fieldnames = [
288                 'iter',

```



```

318         'strtpreds': ', '.join([clabels[v] for v in treg['
319             classes']])
320             # true predicted class labels
321             'ninst': treg['ninst'] # number of training instances in
322             region
323         })
324         for ind in range(len(ps)): # increment base representation
325             of region for next for loop
326             qs[ind] += 1 # increment by 1
327             if qs[ind] > ps[ind]: qs[ind] = 0 # new leading one
328             else: break # same leading one
329
330     # Export final reports of detailed regions (with nonduplicate entries)
331     dfrrp = pd.read_csv(f"{outdir}/{outrrepwdfile}")
332     dfrrpn = nondup(dfrrp, ndcols=[['iter', 'ordvars', 'strvars']], intcols
333         =['iter'])
334     dfrrpn.to_csv( # with nonduplicate entries
335         f"{outdir}/{outrrepndfile}",
336         sep=',', na_rep='',
337         header=True, index=False
338     )
339
340     print(f"{dfrrp.head()}\n") # detailed decision regions (with duplicate
341     entries)
342     print(f"{dfrrpn.head()}\n") # detailed decision regions (with nonduplicate
343     entries)
344
345     # Reexamination of CPLEX Results
346
347     # Additional output files
348     outexffile = f"{ts}-exam-full.csv" # full cplex reexamination
349     outexdfile = f"{ts}-exam-diff.csv" # difference in new decision regions
350     outexnfile = f"{ts}-exam-difnum.csv" # number of difference
351
352     # Convert full coordinate to position in new feature space
353     def tonpos(citer, coord):

```

```

348     ls = list()
349     for j in tsels[citer]['js']:
350         if tcuts[citer][j]['type'] == 'cont':
351             ls.append(itvpos(coord[j-1], tcuts[citer][j]['cuts']))
352         else:
353             ls.append(tcuts[citer][j]['cuts'][coord[j-1]])
354     return tuple(ls)
355
356 # Compute new numerical region from given position to new feature space
357 def tonreg(citer, pos):
358     pcutn = np.array(tsels[citer]['ps'], dtype=np.int16)
359     pncum = np.cumprod(np.append([1], pcutn[0:-1]+1), dtype=np.int16)
360     return np.dot(pncum, pos)
361
362 dfpn = dfp.copy() # copy of individual result of cplex prediction
363 dfpn = dfpn[dfpn['iter'].isin(tsels.keys())] # exclude iterations of no
       feature selection
364
365 nregdc = dict() # new numerical regions in all iterations
366 for citer, info in tsels.items():
367     nregdc[citer] = calregs(pcuo=pcuto, sidx=np.array(info['js'])-1)
368 dfpn['creg'] = dfpn.apply(lambda x: nregdc[x.iter][x.region], axis=1) #
       new region based on cplex result
369 dfpn['cpred'] = dfpn.apply(lambda x: ttregs[x.iter][x.creg]['classes'],
       axis=1) # cplex predicted class
370
371 dfc = pd.merge(df, dfpn, how='right', left_on=df.index+1, right_on='id',
       suffixes='', '_pn')) # include instance
372 del dfc['class_pn']
373 cols = dfc.columns.tolist()
374 new_cols = cols[len(pcuo)+1:len(pcuo)+3] + cols[0:len(pcuo)+1] + cols
       [-4:]
375 dfc = dfc[new_cols]
376 dfc = dfc.rename(columns={'region': 'rreg', 'predict': 'rpred'})
377 dfc['rpred'] = dfc['rpred'].apply(strtaset)
378

```

```
379 dfc['coord'] = dfc.iloc[:,2:len(pcuto)+2].apply(tuple, axis=1) # full
    original coordinate
380 dfc['tpos'] = dfc.apply(lambda x: tonpos(x.iter, x.coord), axis=1) # true
    position in new feature space
381 dfc['treg'] = dfc.apply(lambda x: tonreg(x.iter, x.tpos), axis=1) # true
    decision region
382 dfc['tpred'] = dfc.apply(lambda x: ttregs[x.iter][x.treg]['classes'], axis
    =1) # true predicted class
383
384 dfcd = dfc[dfc['creg'] != dfc['treg']] # new cplex region differs from new
    true region
385 dfcn = dfcd.groupby('iter').size().reset_index(name='dnum') # number of
    difference
386
387 print(f"{dfcn}\n") # display number of difference in region recalculation
388 print(f"{dfcd}\n") # display difference in new regions
389
390 # Export cplex reexamination results
391 dfc.to_csv(f"{outdir}/{outexffile}", header=True, index=False) # full
    cplex reexamination
392 dfcd.to_csv(f"{outdir}/{outexdfile}", header=True, index=False) #
    difference in new decision regions
393 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

Preslected Variable	Insurance Coverage Type (GRP, DIR, PUB)			
	NNN	NNY	NY_	Y1Y
<b>A_AGE: Age</b>				
Universe: All persons				
(1.917, 18.6]	4	8	2	0
(18.6, 35.2]	10	2	1	4
(35.2, 51.8]	5	1	5	2
(51.8, 68.4]	1	4	8	6
(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
1: Employed - at work	8	3	7	9
2: Employed - absent	0	0	3	1
3: Unemployed - on layoff	1	1	0	0
4: Unemployed - looking	1	1	1	0
5: Not in labor force - retired	0	5	5	9
6: Not in labor force - disabled	0	2	1	0
				75

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

Preselected Variable	Insurance Coverage Type (GRP, DIR, PUB)				
	NNN	NNY	NY_	Y1Y	YNN
7: Not in labor force - other	6	3	1	1	2
<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%

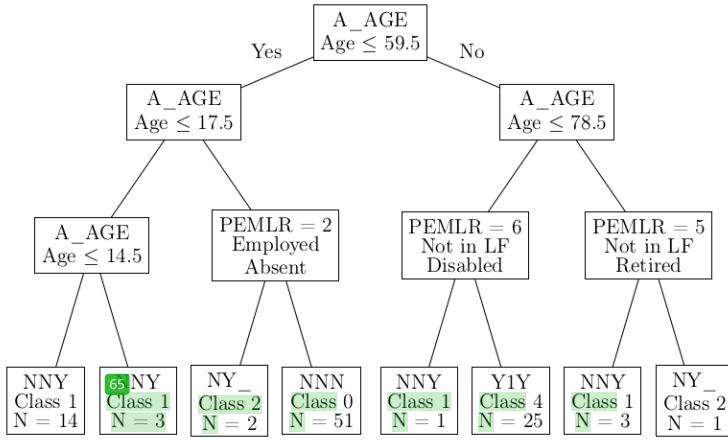


Figure 5.2: Gini-based decision tree with depth 4, 11 non-leaf nodes and 12 leaf nodes giving training accuracy of 50%

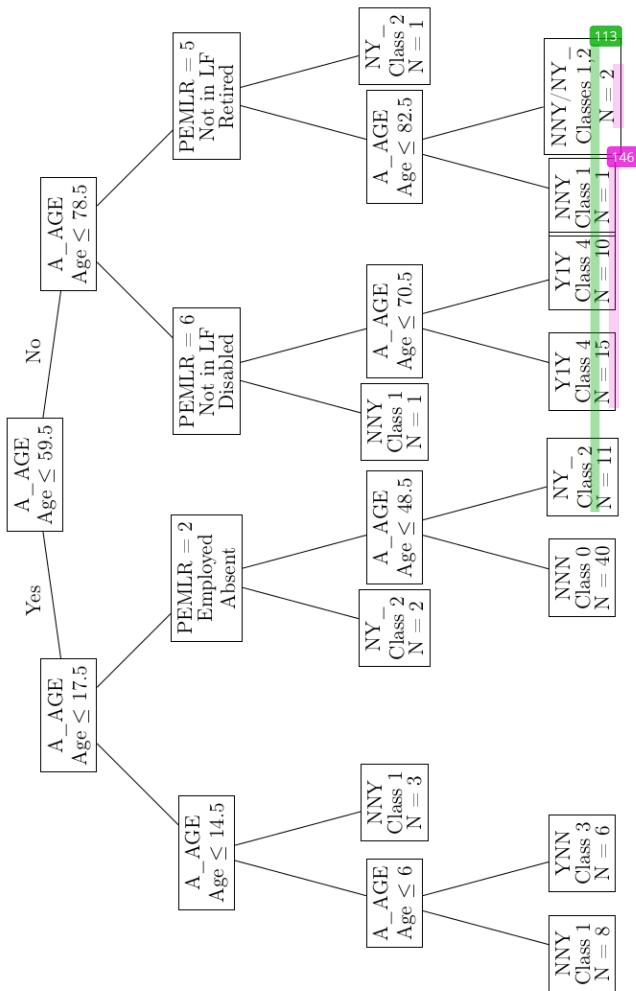
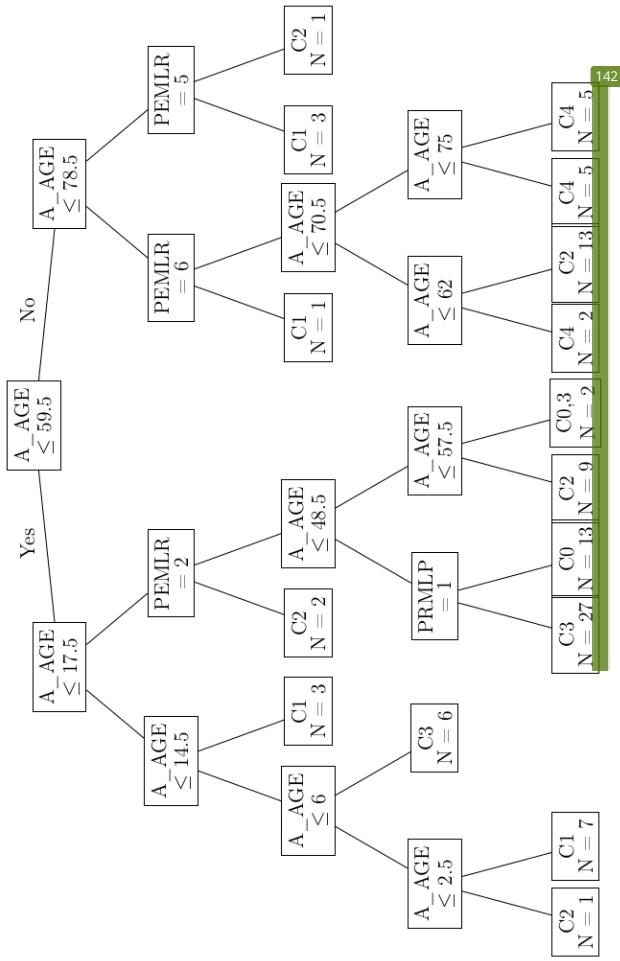


Figure 5.3: Gini-based decision tree with depth 5, 15 non-leaf nodes and 16 leaf nodes giving training accuracy of 54%



Code 5.1: Gini-based decision tree classifier

```

1 14 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
32     # One-hot encoding
33     feat_cat = list(df_info[df_info['type'] == 'Categorical']['variable'])
34     for v in feat_cat:
35         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
68     rules = export_text(clf, feature_names=list(X.columns))
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"
104     outruledir = f"{outdatadir}/rules"
105     outpreddir = f"{outdatadir}/prediction"
106     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
139             postfix = f"mdepth-{mdepth}-mleaves-{mleaves}"
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. Certain training instances do not exactly lie until iteration 10 in their CPLEX decision regions, whether original or merged, as indicated by inconsistency between both CPLEX and true training accuracies when both region types are assumed to generate identical predictions. 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	Specification	Num of Splitting Values				Num of Boxes	Training Accuracy (%)	Execution Time (min)
		A\_AGE	PEMLR	SS\_YN	Total			
Decision tree	Depth of 3	4	3	0	7	8	45	0.08
	Depth of 4	8	3	0	11	12	50	
	Depth of 5	12	3	0	15	16	54	
Proposed classifier	Iteration 13	3	3	0	6	16	51	78.88
	Iteration 14	3	3	0	6	16	51	82.02
	Iteration 15	3	3	0	6	16	51	209.93

Table 5.3: Splitting values on features of multiple decision tree of depths 3 to 5 and proposed classifier in iterations 13 to 15

Classification Model		Splitting Values				Training Accuracy (%)
Model	Specification	A_AGE	PEMLR	SS_YN		
Decision tree	Depth of 3	14.5, 17.5, 59.5, 78.5	{2}, {5}, {6}, {0, 1, 3, 4, 7}	—	—	45
	Depth of 4	6, 14.5, 17.5, 48.5, 59.5, 70.5, 78.5, 82.5	{2}, {5}, {6}, {0, 1, 3, 4, 7}	—	—	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}, {0, 1, 3, 4, 7}	—	—	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	PEMLR	Categorical	0		1	Employed - at work 18	
					3		Unemployed - on layoff
					7		Not in labor force - other
					5		Not in labor force - retired
					0		NIU
	SS_YN	Categorical	0		2	Employed - absent Unemployed - looking 32	
					2		
					4		
					6		Not in labor force - disabled
					1		No
3	PEMLR	Categorical	0		1	Yes NIU (aged below 15)	
					1		
					0		
					2		
					0		
	PEMLR	Categorical	0		1	Employed - at work 18	
					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	Index	Member
	Index	Symbol	Type			
					2	Employed - absent
					4	Unemployed - looking <sup>32</sup>
					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 <sup>18</sup>		
			3	Unemployed - on layoff		
			7	Not in labor force - other		
			5	Not in labor force - retired		
			3	NIU		
			0			
			2	Employed - absent		
			4	Unemployed - looking <sup>32</sup>		
			6	Not in labor force - disabled		
3	SS_YN	Categorical	0			
			1		2	
			1		1	

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 <sup>18</sup>
					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 <sup>32</sup>
					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 <sup>32</sup>
					3	Unemployed - on layoff
					7	Not in labor force - other
				1	2	Employed - absent

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

Iteration	Selected Variable			Group	Member	
	Index	Symbol	Type		Index	Label
				2	5	Not in labor force - retired <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)
3	SS_YN	Categorical	0			
7	2	PEMLR	Categorical	0	1	Employed - at work <sup>18</sup>
					2	Employed - absent
				4	4	Unemployed - looking
				No	NIU	
				Yes	Yes	
				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	Index	Member
	Index	Symbol	Type			
8	2	PEMLR	Categorical	0	2	Employed - absent
				1	1	Employed - at work
				2	6	Not in labor force - disabled <sup>29</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
				3	0	NIU (aged below 15)
				2	0	
				1	1	No
						NIU (aged below 15)
						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	( $-\infty, 24.01$ )	Not in labor force - retired	
				1	(24.01, 40.99)	NIU	
				2	(40.99, 64.99)	Unemployed - on layoff	125
				3		Not in labor force - disabled	
				6			
	2	PEMLR	Categorical	0	(64.99, $\infty$ )	Above 65	
				1	2	Employed - absent	
				2	1	Employed - at work	32
				3	1	Not in labor force - other	
				2	7	Unemployed - looking	29
				2	4	Not in labor force - retired	
				3	5	NIU	
				3	0	Unemployed - on layoff	
				6	3	Not in labor force - disabled	
					6		

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

Iteration	Selected Variable			Group	Member				
	Index	Symbol	Type		Index	Label			
12	1	A_AGE	Continuous	0	( $-\infty, 24.99$ )	Below 24			
				1	(24.99, 40.01)	Between 25 and 40			
				2	(40.00, 64.01)	Between 41 and 64			
				3	(64.01, $\infty$ )	Above 65			
2	PEMLR	Categorical		0	2	Employed - absent			
				1	1	Employed - at work			
				2	4	Unemployed - looking			
				5	29	Not in labor force - retired			
				7	29	Not in labor force - other			
				3	0	NIU			
				3	3	Unemployed - on layoff			
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			
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	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	1	(24.01, 55.99)	Between 25 and 55	
			2	2	(55.99, 64.99)	Between 56 and 64	
			3	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
7	(2,3)	PEMLR, SS\_YN	0	(0,0)	$\{1, 2, 4\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_ , YNN, Y1Y	0
			1	(1,0)	$\emptyset \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_ , YNN, Y1Y	0
			2	(2,0)	$\{0, 3, 6, 7\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_ , YNN, Y1Y	0
			3	(3,0)	$\{5\} \times \emptyset$	0,1,2,3,4	NNN, NNY, NY_ , YNN, Y1Y	0

Table 5.6: Decision regions and predicted class labels across all iterations (continued)

Iter	Selected Variables		Decision Region			Predicted Classes		Num
	Tuple	Symbol	Ind	Tuple	Cross Product	Ind	Label	
4	(0,1)		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	YY	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 $_-,$ YY	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	YY	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 <sub>-</sub> , YNN, Y1Y	0
			1	(1,0)	(24.99, 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)	( $-\infty, 24.99$ ) $\times \{1\}$	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 <sub>-</sub>	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 <sub>-</sub>	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 <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	
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 $_-$ , YNN, Y1Y	0
			1	(1,0)	(24.01, 55.99) $\times \{2\}$	2	NY $_-$	2
			2	(2,0)	(55.99, 64.99) $\times \{2\}$	4	Y1Y	1
			3	(3,0)	(64.99, $\infty$ ) $\times \{2\}$	2	NY $_-$	1
			4	(0,1)	( $-\infty, 24.01$ ) $\times \{1\}$	0	NNN	7
			5	(1,1)	(24.01, 55.99) $\times \{1\}$	3	YNN	23
			6	(2,1)	(55.99, 64.99) $\times \{1\}$	3	YNN	4
			7	(3,1)	(64.99, $\infty$ ) $\times \{1\}$	2	NY $_-$	5
			8	(0,2)	( $-\infty, 24.01$ ) $\times \{3, 4, 5, 7\}$	1	NNY	6
			9	(1,2)	(24.01, 55.99) $\times \{3, 4, 5, 7\}$	0	NNN	9
			10	(2,2)	(55.99, 64.99) $\times \{3, 4, 5, 7\}$	2	NY $_-$	7
			11	(3,2)	(64.99, $\infty$ ) $\times \{3, 4, 5, 7\}$	4	Y1Y	17
			12	(0,3)	( $-\infty, 24.01$ ) $\times \{0, 6\}$	1	NNY	15
			13	(1,3)	(24.01, 55.99) $\times \{0, 6\}$	1	NNY	1
			14	(2,3)	(55.99, 64.99) $\times \{0, 6\}$	2	NY $_-$	1
			15	(3,3)	(64.99, $\infty$ ) $\times \{0, 6\}$	1	NNY	1

Table 5.7: Inconsistency between numerical CPLEX and true decision regions

Iter	Training Instance				Reported				CPLEX				True		
	ID	A_AGE	PEMLR	SSYN	Target	Region	Predict	Region	Predict	Region	Predict	Region	Predict	Region	Predict
2	8	4	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1	11	1	11	1
10	12	0	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1	11	1	11	1
20	10	0	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1	11	1	11	1
21	85	5	1	1	22	4	5	5	0, 1, 2, 3, 4	6	4	6	4	6	4
22	74	5	1	1	22	4	5	5	0, 1, 2, 3, 4	6	4	6	4	6	4
23	64	5	1	1	22	4	5	5	0, 1, 2, 3, 4	6	4	6	4	6	4
24	73	5	1	1	22	4	5	5	0, 1, 2, 3, 4	6	4	6	4	6	4
26	5	0	0	1	38	1	9	9	0, 1, 2, 3, 4	11	1	11	1	11	1
27	4	0	0	1	38	1	9	9	0, 1, 2, 3, 4	11	1	11	1	11	1
28	10	0	0	1	38	1	9	9	0, 1, 2, 3, 4	11	1	11	1	11	1
29	54	6	1	1	26	1	6	6	4	4	7	1	1	7	1
30	3	0	0	1	38	1	9	9	0, 1, 2, 3, 4	11	1	11	1	11	1
33	17	4	1	1	26	1	6	6	4	4	7	1	1	7	1
35	77	6	1	1	26	1	6	6	4	4	7	1	1	7	1
36	5	0	0	1	38	1	9	9	0, 1, 2, 3, 4	11	1	11	1	11	1
37	80	5	1	1	22	4	5	5	0, 1, 2, 3, 4	6	4	6	4	6	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	Predict	Region	Predict	Region	Predict	Region
40	21	7	1	1	14	2	3	2	4	4	2, 4			
44	79	1	1	2	14	2	3	2	4	4	2, 4			
47	5	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1			
48	76	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
51	2	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1			
53	67	1	1	2	14	2	3	2	4	4	2, 4			
54	67	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
56	85	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
58	70	2	1	2	26	1	6	4	7	7	1			
60	56	6	1	2	26	1	6	4	7	7	1			
64	63	1	1	3	14	2	3	2	4	4	2, 4			
65	14	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
74	4	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
75	12	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
78	7	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
87	73	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4	4			
90	76	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4	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	Predict	Region	Predict	Region	Predict	Region
91	77	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
93	71	1	1	4	14	2	3	2	4	4	2, 4			
94	70	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
95	78	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
96	67	7	1	4	14	2	3	2	4	4	2, 4			
97	71	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
98	66	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
99	67	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
3	8	4	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
10	12	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
20	10	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
21	85	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
22	74	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
23	64	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
24	73	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
26	5	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1				

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	Predict	Region	Predict	Region	Predict	Region
27	4	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
28	10	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
29	54	6	1	1	26	1	6	4	7	1	1	1	1	1
30	3	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
33	17	4	1	1	26	1	6	4	7	1	1	1	1	1
35	77	6	1	1	26	1	6	4	7	1	1	1	1	1
36	5	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
37	80	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
40	21	7	1	1	14	2	3	2	4	4	4	4	4	4
44	79	1	1	2	14	2	3	2	4	4	4	4	4	4
47	5	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
48	76	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
51	2	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
53	67	1	1	2	14	2	3	2	4	4	4	4	4	4
54	67	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
56	85	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
58	70	2	1	2	26	1	6	4	7	1	1	1	1	1

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	Predict	Region	Predict	Region	Predict	Region
60	56	6	1	2	26	1	6	6	4	7	7	1	1	
64	63	1	1	3	14	2	3	2	4	4	4	2, 4		
65	14	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
74	4	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
75	12	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
78	7	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
87	73	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
90	76	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
91	77	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
93	71	1	1	4	14	2	3	2	4	4	4	2, 4		
94	70	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
95	78	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
96	67	7	1	4	14	2	3	2	4	4	4	2, 4		
97	71	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
98	66	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
99	67	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	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	Predict	Region	Predict	Region	Predict	Region	Predict
4	8	4	0	0	0	38	1	9	0,1,2,3,4	11	1	11	1	11	1
10	12	0	0	0	0	38	1	9	0,1,2,3,4	11	1	11	1	11	1
20	10	0	0	0	0	38	1	9	0,1,2,3,4	11	1	11	1	11	1
21	85	5	1	1	1	22	4	5	0,1,2,3,4	6	4	6	4	6	4
22	74	5	1	1	1	22	4	5	0,1,2,3,4	6	4	6	4	6	4
23	64	5	1	1	1	22	4	5	0,1,2,3,4	6	4	6	4	6	4
24	73	5	1	1	1	22	4	5	0,1,2,3,4	6	4	6	4	6	4
26	5	0	0	1	1	38	1	9	0,1,2,3,4	11	1	11	1	11	1
27	4	0	0	1	1	38	1	9	0,1,2,3,4	11	1	11	1	11	1
28	10	0	0	1	1	38	1	9	0,1,2,3,4	11	1	11	1	11	1
29	54	6	1	1	1	26	1	6	4	7	1	7	1	7	1
30	3	0	0	1	1	38	1	9	0,1,2,3,4	11	1	11	1	11	1
33	17	4	1	1	1	26	1	6	4	7	1	7	1	7	1
35	77	6	1	1	1	26	1	6	4	7	1	7	1	7	1
36	5	0	0	1	1	38	1	9	0,1,2,3,4	11	1	11	1	11	1
37	80	5	1	1	1	22	4	5	0,1,2,3,4	6	4	6	4	6	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	Predict	Region	Predict	Region	Predict	Region
40	21	7	1	1	14	2	3	2	4	4	2, 4			
44	79	1	1	2	14	2	3	2	4	4	2, 4			
47	5	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1			
48	76	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
51	2	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1			
53	67	1	1	2	14	2	3	2	4	4	2, 4			
54	67	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
56	85	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4			
58	70	2	1	2	26	1	6	4	7	7	1			
60	56	6	1	2	26	1	6	4	7	7	1			
64	63	1	1	3	14	2	3	2	4	4	2, 4			
65	14	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
74	4	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
75	12	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
78	7	0	0	3	38	1	9	0, 1, 2, 3, 4	11	1	1			
87	73	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4	4			
90	76	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4	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	Predict	Region	Predict	Region	Predict	Region
91	77	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
93	71	1	1	4	14	2	3	2	4	4	2, 4			
94	70	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
95	78	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
96	67	7	1	4	14	2	3	2	4	4	2, 4			
97	71	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
98	66	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
99	67	5	1	4	22	4	5	0, 1, 2, 3, 4	6	4				
5	8	4	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
10	12	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
20	10	0	0	0	38	1	9	0, 1, 2, 3, 4	11	1				
21	85	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
22	74	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
23	64	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
24	73	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4				
26	5	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1				

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	Predict	Region	Predict	Region	Predict	Region
27	4	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
28	10	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
29	54	6	1	1	26	1	6	4	7	1	1	1	1	1
30	3	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
33	17	4	1	1	26	1	6	4	7	1	1	1	1	1
35	77	6	1	1	26	1	6	4	7	1	1	1	1	1
36	5	0	0	1	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
37	80	5	1	1	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
40	21	7	1	1	14	2	3	2	4	4	4	4	4	4
44	79	1	1	2	14	2	3	2	4	4	4	4	4	4
47	5	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
48	76	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
51	2	0	0	2	38	1	9	0, 1, 2, 3, 4	11	1	1	1	1	1
53	67	1	1	2	14	2	3	2	4	4	4	4	4	4
54	67	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
56	85	5	1	2	22	4	5	0, 1, 2, 3, 4	6	4	4	4	4	4
58	70	2	1	2	26	1	6	4	7	1	1	1	1	1

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	Predict	Region	Predict	Region	Predict	Region
60	56	6	1	2	26	1	6	6	4	7	7	1	1	
64	63	1	1	3	14	2	3	2	4	4	4	2, 4		
65	14	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
74	4	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
75	12	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
78	7	0	0	3	38	1	9	0, 1, 2, 3, 4	11	11	11	1	1	
87	73	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
90	76	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
91	77	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
93	71	1	1	4	14	2	3	2	4	4	4	2, 4		
94	70	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
95	78	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
96	67	7	1	4	14	2	3	2	4	4	4	2, 4		
97	71	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
98	66	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	4	
99	67	5	1	4	22	4	5	0, 1, 2, 3, 4	6	6	6	4	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	Predict	Region	Predict
6	8	4	0	0	0	38	1	9	0,1,2,3,4	11	1
10	12	0	0	0	0	38	1	9	0,1,2,3,4	11	1
20	10	0	0	0	0	38	1	9	0,1,2,3,4	11	1
21	85	5	1	1	1	22	4	5	2	6	4
22	74	5	1	1	1	22	4	5	2	6	4
23	64	5	1	1	1	22	4	5	2	6	4
24	73	5	1	1	1	22	4	5	2	6	4
26	5	0	0	1	1	38	1	9	0,1,2,3,4	11	1
27	4	0	0	1	1	38	1	9	0,1,2,3,4	11	1
28	10	0	0	1	1	38	1	9	0,1,2,3,4	11	1
29	54	6	1	1	1	26	1	6	4	7	1
30	3	0	0	1	1	38	1	9	0,1,2,3,4	11	1
33	17	4	1	1	1	26	1	6	4	7	1
35	77	6	1	1	1	26	1	6	4	7	1
36	5	0	0	1	1	38	1	9	0,1,2,3,4	11	1
37	80	5	1	1	1	22	4	5	2	6	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	Predict	Region
40	21	7	1	1	14	2,3	3	0,3	4	2,4
44	79	1	1	2	14	2,3	3	0,3	4	2,4
47	5	0	0	2	38	1	9	0,1,2,3,4	11	1
48	76	5	1	2	22	4	5	2	6	4
51	2	0	0	2	38	1	9	0,1,2,3,4	11	1
53	67	1	1	2	14	2,3	3	0,3	4	2,4
54	67	5	1	2	22	4	5	2	6	4
56	85	5	1	2	22	4	5	2	6	4
58	70	2	1	2	18	2	4	2,4	5	2
60	56	6	1	2	26	1	6	4	7	1
64	63	1	1	3	14	2,3	3	0,3	4	2,4
65	14	0	0	3	38	1	9	0,1,2,3,4	11	1
74	4	0	0	3	38	1	9	0,1,2,3,4	11	1
75	12	0	0	3	38	1	9	0,1,2,3,4	11	1
78	7	0	0	3	38	1	9	0,1,2,3,4	11	1
87	73	5	1	4	22	4	5	2	6	4
90	76	5	1	4	22	4	5	2	6	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	Predict	Region	Predict	Region	Predict	Region
91	77	5	1	4	22	4	5	5	2	6	6	4		
93	71	1	1	4	14	2, 3	3	0, 3	4	4	4	2, 4		
94	70	5	1	4	22	4	5	5	2	6	6	4		
95	78	5	1	4	22	4	5	5	2	6	6	4		
96	67	7	1	4	14	2, 3	3	0, 3	4	4	4	2, 4		
97	71	5	1	4	22	4	5	5	2	6	6	4		
98	66	5	1	4	22	4	5	5	2	6	6	4		
99	67	5	1	4	22	4	5	5	2	6	6	4		
7	1	24	1	2	0	14	3	3	0, 1, 2, 3, 4	4	4	3		
2	58	7	2	0	22	0	5	5	0, 1, 2, 3, 4	6	6	0		
3	24	1	2	0	14	3	3	0, 1, 2, 3, 4	4	4	3			
4	40	7	2	0	22	0	5	5	0, 1, 2, 3, 4	6	6	0		
5	24	1	2	0	14	3	3	0, 1, 2, 3, 4	4	4	3			
6	26	1	2	0	14	3	3	0, 1, 2, 3, 4	4	4	3			
7	18	7	2	0	22	0	5	5	0, 1, 2, 3, 4	6	6	0		
8	4	0	0	0	22	0	5	5	0, 1, 2, 3, 4	6	6	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	Predict	Region	Predict	Region	Predict	Region
9	38	3	2	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
10	12	0	0	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
11	46	7	2	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
12	26	1	2	0	14	3	3	0, 1, 2, 3, 4	4	3	0	0	0	0
13	35	7	2	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
14	19	7	2	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
15	29	4	2	0	14	3	3	0, 1, 2, 3, 4	4	3	0	0	0	0
16	24	0	2	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
17	35	1	2	0	14	3	3	0, 1, 2, 3, 4	4	3	0	0	0	0
18	48	1	2	0	14	3	3	0, 1, 2, 3, 4	4	3	0	0	0	0
19	41	1	2	0	14	3	3	0, 1, 2, 3, 4	4	3	0	0	0	0
20	10	0	0	0	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0
21	85	5	1	1	38	4	9	0, 1, 2, 3, 4	11	4	0	0	0	0
22	74	5	1	1	38	4	9	0, 1, 2, 3, 4	11	4	0	0	0	0
23	64	5	1	1	38	4	9	0, 1, 2, 3, 4	11	4	0	0	0	0
24	73	5	1	1	38	4	9	0, 1, 2, 3, 4	11	4	0	0	0	0
25	15	7	2	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	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	Predict	Region	Predict	Region	Predict	Region	Predict
26	5	0	0	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0	
27	4	0	0	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0	
28	10	0	0	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0	
29	54	6	1	1	34	1	8	2	10	1					
30	3	0	0	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0	
31	45	3	2	1	22	0	5	0, 1, 2, 3, 4	6	0	0	0	0	0	
32	28	1	2	1	14	3	3	0, 1, 2, 3, 4	4	3					
33	17	4	1	1	26	2	6	0	8	2					
34	57	1	2	1	14	3	3	0, 1, 2, 3, 4	4	3					
35	77	6	1	1	34	1	8	2	10	1					
36	5	0	0	1	22	0	5	0, 1, 2, 3, 4	6	0					
37	80	5	1	1	38	4	9	0, 1, 2, 3, 4	11	4					
38	16	1	2	1	14	3	3	0, 1, 2, 3, 4	4	3					
39	57	7	2	1	22	0	5	0, 1, 2, 3, 4	6	0					
40	21	7	1	1	34	1	8	2	10	1					
41	56	4	2	2	14	3	3	0, 1, 2, 3, 4	4	3					
42	64	5	2	2	26	2	6	0	7	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	Predict	Region	Predict	Region	Predict	Region	Predict
43	38	2	2	2	14	3	3	0, 1, 2, 3, 4	4	3	3	0, 1, 2, 3, 4	4	3	
44	79	1	1	2	26	2	6	0	8	8	2	0	0	2	2
45	57	7	2	2	22	0	5	0, 1, 2, 3, 4	6	6	0	0	0	0	0
46	65	1	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3
47	5	0	0	2	22	0	5	0, 1, 2, 3, 4	6	6	0	0, 1, 2, 3, 4	6	0	0
48	76	5	1	2	38	4	9	0, 1, 2, 3, 4	11	11	4	0, 1, 2, 3, 4	11	4	4
49	49	1	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3
50	37	2	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3
51	2	0	0	2	22	0	5	0, 1, 2, 3, 4	6	6	0	0, 1, 2, 3, 4	6	0	0
52	41	1	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3
53	67	1	1	2	26	2	6	0	8	8	2	0	0	2	2
54	67	5	1	2	38	4	9	0, 1, 2, 3, 4	11	11	4	0, 1, 2, 3, 4	11	4	4
55	63	5	2	2	26	2	6	0	7	7	2	0	0	2	2
56	85	5	1	2	38	4	9	0, 1, 2, 3, 4	11	11	4	0, 1, 2, 3, 4	11	4	4
57	19	1	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3
58	70	2	1	2	26	2	6	0	8	8	2	0	0	2	2
59	38	1	2	2	14	3	3	0, 1, 2, 3, 4	4	4	3	0, 1, 2, 3, 4	4	3	3

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	Predict	Region	Predict	Region	Predict	Region	Predict
60	56	6	1	2	34	1	8	2	10	10	1	10	1	10	1
61	29	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
62	26	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
63	59	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
64	63	1	1	3	26	2	6	0	8	8	2	8	2	8	2
65	14	0	0	3	22	0	5	0, 1, 2, 3, 4	6	6	0	6	0	6	0
66	22	4	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
67	25	7	2	3	22	0	5	0, 1, 2, 3, 4	6	6	0	6	0	6	0
68	18	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
69	25	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
70	46	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
71	40	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
72	29	4	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
73	33	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	4	3	4	3
74	4	0	0	3	22	0	5	0, 1, 2, 3, 4	6	6	0	6	0	6	0
75	12	0	0	3	22	0	5	0, 1, 2, 3, 4	6	6	0	6	0	6	0
76	51	7	2	3	22	0	5	0, 1, 2, 3, 4	6	6	0	6	0	6	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	Predict	Region	Predict	Region	Predict	Region	Predict
77	29	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
78	7	0	0	3	22	0	5	0, 1, 2, 3, 4	6	6	0	0	0, 1, 2, 3, 4	0	
79	51	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
80	41	1	2	3	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
81	78	5	2	4	26	2	6	0	7	7	2	2	0	7	2
82	60	2	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
83	27	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
84	65	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
85	22	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
86	42	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
87	73	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4	4	0, 1, 2, 3, 4	4	
88	45	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
89	26	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
90	76	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4	4	0, 1, 2, 3, 4	4	
91	77	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4	4	0, 1, 2, 3, 4	4	
92	27	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3	3	0, 1, 2, 3, 4	3	
93	71	1	1	4	26	2	6	0	8	8	2	2	0	8	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	Predict	Region	Predict	Region	Predict	Region
94	70	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4			
95	78	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4			
96	67	7	1	4	34	1	8	2	10	10	1			
97	71	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4			
98	66	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4			
99	67	5	1	4	38	4	9	0, 1, 2, 3, 4	11	11	4			
100	61	1	2	4	14	3	3	0, 1, 2, 3, 4	4	4	3			
8	8	4	0	0	34	1	8	2	10	10	1			
10	12	0	0	0	34	1	8	2	10	10	1			
20	10	0	0	0	34	1	8	2	10	10	1			
21	85	5	1	1	38	4	9	2	11	11	4			
22	74	5	1	1	38	4	9	2	11	11	4			
23	64	5	1	1	38	4	9	2	11	11	4			
24	73	5	1	1	38	4	9	2	11	11	4			
26	5	0	0	1	34	1	8	2	10	10	1			
27	4	0	0	1	34	1	8	2	10	10	1			

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	Predict	Region	Predict	Region	Predict	Region	Predict
28	10	0	0	1	34	1	8	2	10	10	1	10	1	10	1
29	54	6	1	1	30	2	7	0, 1, 2, 3, 4	9	9	2	9	2	9	2
30	3	0	0	1	34	1	8	2	10	10	1	10	1	10	1
33	17	4	1	1	34	1	8	2	10	10	1	10	1	10	1
35	77	6	1	1	30	2	7	0, 1, 2, 3, 4	9	9	2	9	2	9	2
36	5	0	0	1	34	1	8	2	10	10	1	10	1	10	1
37	80	5	1	1	38	4	9	2	11	11	4	11	4	11	4
40	21	7	1	1	34	1	8	2	10	10	1	10	1	10	1
44	79	1	1	2	30	2	7	0, 1, 2, 3, 4	9	9	2	9	2	9	2
47	5	0	0	2	34	1	8	2	10	10	1	10	1	10	1
48	76	5	1	2	38	4	9	2	11	11	4	11	4	11	4
51	2	0	0	2	34	1	8	2	10	10	1	10	1	10	1
53	67	1	1	2	30	2	7	0, 1, 2, 3, 4	9	9	2	9	2	9	2
54	67	5	1	2	38	4	9	2	11	11	4	11	4	11	4
56	85	5	1	2	38	4	9	2	11	11	4	11	4	11	4
58	70	2	1	2	26	2	6	0, 1, 2, 3, 4	8	8	2	8	2	8	2
60	56	6	1	2	30	2	7	0, 1, 2, 3, 4	9	9	2	9	2	9	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	Predict	Region	Predict	Region	Predict	Region	Predict	Region
64	63	1	1	3	30	2	7	0, 1, 2, 3, 4	9	9	2					
65	14	0	0	3	34	1	8	2	10	10	1					
74	4	0	0	3	34	1	8	2	10	10	1					
75	12	0	0	3	34	1	8	2	10	10	1					
78	7	0	0	3	34	1	8	2	10	10	1					
87	73	5	1	4	38	4	9	2	11	11	4					
90	76	5	1	4	38	4	9	2	11	11	4					
91	77	5	1	4	38	4	9	2	11	11	4					
93	71	1	1	4	30	2	7	0, 1, 2, 3, 4	9	9	2					
94	70	5	1	4	38	4	9	2	11	11	4					
95	78	5	1	4	38	4	9	2	11	11	4					
96	67	7	1	4	34	1	8	2	10	10	1					
97	71	5	1	4	38	4	9	2	11	11	4					
98	66	5	1	4	38	4	9	2	11	11	4					
99	67	5	1	4	38	4	9	2	11	11	4					
9	8	4	0	0	34	1	8	2	10	10	1					

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	Predict	Region	Predict	Region	Predict	Region
10	12	0	0	0	34	1	8	2	10	10	1	1	1	1
20	10	0	0	0	34	1	8	2	10	10	1	1	1	1
21	85	5	1	1	38	4	9	2	11	11	4	4	4	4
22	74	5	1	1	38	4	9	2	11	11	4	4	4	4
23	64	5	1	1	38	4	9	2	11	11	4	4	4	4
24	73	5	1	1	38	4	9	2	11	11	4	4	4	4
26	5	0	0	1	34	1	8	2	10	10	1	1	1	1
27	4	0	0	1	34	1	8	2	10	10	1	1	1	1
28	10	0	0	1	34	1	8	2	10	10	1	1	1	1
29	54	6	1	1	34	1	8	2	10	10	1	1	1	1
30	3	0	0	1	34	1	8	2	10	10	1	1	1	1
33	17	4	1	1	34	1	8	2	10	10	1	1	1	1
35	77	6	1	1	34	1	8	2	10	10	1	1	1	1
36	5	0	0	1	34	1	8	2	10	10	1	1	1	1
37	80	5	1	1	38	4	9	2	11	11	4	4	4	4
40	21	7	1	1	34	1	8	2	10	10	1	1	1	1
44	79	1	1	2	30	2	7	0, 1, 2, 3, 4	9	9	2	2	2	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	Predict	Region	Predict	Region	Predict	Region
47	5	0	0	2	34	1	8	2	2	10	10	1	1	
48	76	5	1	2	38	4	9	2	2	11	11	4		
51	2	0	0	2	34	1	8	2	2	10	10	1		
53	67	1	1	2	30	2	7	7	0,1,2,3,4	9	9	2		
54	67	5	1	2	38	4	9	2	2	11	11	4		
56	85	5	1	2	38	4	9	2	2	11	11	4		
58	70	2	1	2	26	2	6	6	0,1,2,3,4	8	8	2		
60	56	6	1	2	34	1	8	2	2	10	10	1		
64	63	1	1	3	30	2	7	7	0,1,2,3,4	9	9	2		
65	14	0	0	3	34	1	8	2	2	10	10	1		
74	4	0	0	3	34	1	8	2	2	10	10	1		
75	12	0	0	3	34	1	8	2	2	10	10	1		
78	7	0	0	3	34	1	8	2	2	10	10	1		
87	73	5	1	4	38	4	9	2	2	11	11	4		
90	76	5	1	4	38	4	9	2	2	11	11	4		
91	77	5	1	4	38	4	9	2	2	11	11	4		
93	71	1	1	4	30	2	7	7	0,1,2,3,4	9	9	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	Predict	Region
94	70	5	1	4	38	4	9	2	11	4
95	78	5	1	4	38	4	9	2	11	4
96	67	7	1	4	34	1	8	2	10	1
97	71	5	1	4	38	4	9	2	11	4
98	66	5	1	4	38	4	9	2	11	4
99	67	5	1	4	38	4	9	2	11	4

## 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>139</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

## APPENDIX A

### CPLEX ENGINE LOG

```
<<< setup

[12] 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)

-----
12 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
24 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      --- 

28 GUB cover cuts applied: 29
Clique cuts applied: 10
Cover cuts applied: 51
Implied bound cuts applied: 242
Flow cuts applied: 6
Mixed integer rounding cuts applied: 186
Zero-half cuts applied: 77
Lift and project cuts applied: 7
Gomory fractional cuts applied: 16

Root node processing (before b&c):

```

```

Real time          = 1.78 sec. (1803.05 ticks)
Parallel b&c, 8 threads:
Real time          = 0.00 sec. (0.00 ticks)
48 Sync time (average) = 0.00 sec.
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)

12 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)

-----
12 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)

-----
12 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      ---
11
Elapsed time = 8.32 sec. (8694.74 ticks, tree = 6.06 MB, solutions = 5)

1551  1044     infeasible          -38.0000    -538.6066   323452      ---
```

11  
Performing restart 1

```

Repeating presolve.
Tried aggregator 1 time.
MIP Presolve eliminated 447 rows and 48 columns.
MIP Presolve modified 2098 coefficients.
Reduced MIP has 3557 rows, 5459 columns, and 21635 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (20.08 ticks)
Tried aggregator 1 time.
MIP Presolve eliminated 1 rows and 0 columns.
MIP Presolve modified 300 coefficients.
Reduced MIP has 3556 rows, 5459 columns, and 21533 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (21.21 ticks)
Represolve time = 0.18 sec. (172.19 ticks)
1603    0      -531.3154    530      -38.0000    Cuts: 989     388606      ---
1603    0      -507.2228    677      -38.0000    Cuts: 989     394828      ---
```

1603	0	-483.0125	703	-38.0000	Cuts: 989	399749	---
1603	0	-460.7636	713	-38.0000	Cuts: 989	407166	---
1603	0	-451.8578	687	-38.0000	Cuts: 989	412425	---
1603	0	-450.6323	805	-38.0000	Cuts: 989	415841	---
1603	0	-432.3823	759	-38.0000	Cuts: 989	423001	---
1603	0	-431.4684	871	-38.0000	Cuts: 989	426280	---
1603	0	-418.8128	830	-38.0000	Cuts: 989	433824	---
1603	0	-417.3207	854	-38.0000	Cuts: 989	437138	998.21%
1603	0	-412.4347	847	-38.0000	Cuts: 989	442602	985.35%
1603	0	-412.0400	919	-38.0000	Cuts: 989	445973	984.32%
1603	0	-411.2439	902	-38.0000	Cuts: 989	449769	980.32%
1603	0	-405.6804	852	-38.0000	Cuts: 989	458674	967.58%
1603	0	-405.2740	821	-38.0000	Cuts: 989	461351	962.76%
1603	0	-400.9631	855	-38.0000	Cuts: 989	468469	952.28%
1603	0	-400.5521	861	-38.0000	Cuts: 989	472372	952.28%
1603	0	-399.9329	893	-38.0000	Cuts: 989	475615	952.28%
1603	0	-397.2191	915	-38.0000	Cuts: 989	483998	944.52%
1603	0	-397.1061	974	-38.0000	Cuts: 989	487153	944.52%
1603	0	-396.3444	963	-38.0000	Cuts: 989	492117	943.01%
1603	0	-395.8637	958	-38.0000	Cuts: 989	496720	939.08%
1603	0	-395.7821	987	-38.0000	Cuts: 989	498869	938.39%
1603	0	-393.1402	932	-38.0000	Cuts: 989	506111	934.58%
1603	0	-393.0317	970	-38.0000	Cuts: 989	508897	934.29%
1603	0	-392.7950	1024	-38.0000	Cuts: 989	513782	933.67%
1603	0	-391.5060	909	-38.0000	Cuts: 989	518934	930.28%
1603	0	-391.4094	932	-38.0000	Cuts: 989	523923	930.02%
1603	0	-390.7816	965	-38.0000	Cuts: 989	530008	928.37%
1603	0	-390.4502	996	-38.0000	Cuts: 989	535960	927.50%
1603	0	-389.7746	975	-38.0000	Cuts: 964	544136	925.72%
1603	0	-389.7179	1028	-38.0000	Cuts: 989	548551	925.57%
1603	0	-389.2127	1004	-38.0000	Cuts: 779	559361	924.24%
1603	0	-389.1541	1044	-38.0000	Cuts: 989	563246	924.09%
1603	0	-388.9571	1041	-38.0000	Cuts: 550	570153	923.57%
1603	0	-388.9327	1102	-38.0000	Cuts: 989	573533	923.51%
1603	0	-388.7011	1102	-38.0000	Cuts: 689	580181	922.90%
1603	0	-388.6569	1153	-38.0000	Cuts: 989	583864	922.78%
1603	2	-388.6569	1138	-38.0000	-388.6569	583864	922.78%
1604	3	-388.2777	1073	-38.0000	-388.2776	587877	921.78%
1605	4	-387.6984	1112	-38.0000	-387.6983	589040	920.26%

1606	5	-387.2199	1098	-38.0000	-387.2194	590656	919.00%
1607	6	-386.8095	1049	-38.0000	-387.0084	594070	918.44%
1609	4	-386.1028	771	-38.0000	-387.0084	595848	918.44%
1610	5	-384.6422	738	-38.0000	-387.0084	598389	918.44%
1612	8	-382.0306	768	-38.0000	-387.0084	613444	918.44%
1615	9	-383.3599	777	-38.0000	-386.9557	622553	918.30%
5							
<b>Elapsed time = 129.55 sec.</b> (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%
49							
<b>Elapsed time = 144.26 sec.</b> (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							
<b>Elapsed time = 158.38 sec.</b> (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%

```

5
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%
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%

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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)

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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.</b> (351762.11 ticks, tree = 158.31 MB, solutions = 5)							
6614	4051	-82.9797	391	-38.0000	-381.9426	5198382	905.11%
7157	4043	-93.9551	441	-38.0000	-381.9426	5261948	905.11%
7752	4029	-193.8106	526	-38.0000	-381.9426	5254080	905.11%
7876	4590	-83.9348	406	-38.0000	-381.8931	5514496	904.98%
7902	4881	-379.3565	919	-38.0000	-381.8926	5595047	904.98%
7940	5145	-286.1287	658	-38.0000	-380.8071	5682204	902.12%
8002	4691	-379.3689	774	-38.0000	-380.6354	5544630	901.67%
8035	5148	-364.5840	753	-38.0000	-380.6354	5716992	901.67%
8098	5346	-324.6925	717	-38.0000	-379.9667	5809066	899.91%
8209	5380	-263.0652	689	-38.0000	-379.9667	5827011	899.91%
5							
<b>Elapsed time = 383.55 sec.</b> (391445.00 ticks, tree = 250.41 MB, solutions = 5)							
8407	5393	-359.8021	721	-38.0000	-379.9667	5914698	899.91%
8481	5521	-262.1683	689	-38.0000	-379.9667	6008749	899.91%
8682	5483	-357.5335	722	-38.0000	-379.9667	6039212	899.91%
8840	5744	-352.5118	627	-38.0000	-379.9667	6188503	899.91%
9256	5975	-93.5178	383	-38.0000	-379.9667	6283362	899.91%
9630	6102	-222.7763	518	-38.0000	-379.9667	6388913	899.91%
9957	6395	-332.9427	599	-38.0000	-379.9667	6566131	899.91%
10206	6704	-102.7602	493	-38.0000	-379.9667	6620570	899.91%
10687	6744	-356.8449	804	-38.0000	-379.9667	6676558	899.91%
10892	7279	-141.4255	485	-38.0000	-379.9667	6824257	899.91%
<b>Elapsed time = 424.74 sec.</b> (430070.66 ticks, tree = 348.74 MB, solutions = 5)							
11285	7549	-266.8955	713	-38.0000	-379.9667	6935942	899.91%
11952	8078	-81.0221	475	-38.0000	-379.9667	7048892	899.91%
12136	8219	-376.5899	831	-38.0000	-379.7943	7146826	899.46%
12316	8696	-376.1854	831	-38.0000	-379.5824	7253016	898.90%
12762	9331	-109.6829	395	-38.0000	-379.5824	7366582	898.90%
13127	9413	-307.3537	678	-38.0000	-379.4554	7421367	898.57%

13190	9725	-370.0417	752	-38.0000	-379.4554	7491216	898.57%
13369	10087	-365.0055	759	-38.0000	-379.4554	7647384	898.57%
13522	9992	-149.8716	574	-38.0000	-379.3906	7584555	898.40%
13675	10455	-169.6634	556	-38.0000	-379.3906	7707912	898.40%
Elapsed time = 472.46 sec. (468453.20 ticks, tree = 464.06 MB, solutions = 5)							
13959	10554	-275.5156	638	-38.0000	-379.3906	7826355	898.40%
14081	10676	-330.6031	587	-38.0000	-379.3841	7853249	898.38%
14380	10903	-299.8063	554	-38.0000	-379.2996	7908540	898.16%
14811	10991	-84.2419	244	-38.0000	-379.2886	7914970	898.13%
15473	11856	-43.7849	209	-38.0000	-379.2886	8097559	898.13%
15621	11659	-375.0829	765	-38.0000	-379.2886	8079509	898.13%
15745	12045	-279.4488	234	-38.0000	-379.2886	8159239	898.13%
16259	12480	-122.9856	334	-38.0000	-379.2886	8247673	898.13%
16560	12619	-150.5545	539	-38.0000	-379.2386	8302917	898.00%
16678	12987	-260.3273	396	-38.0000	-378.8563	8406230	896.99%
Elapsed time = 525.90 sec. (506688.39 ticks, tree = 537.86 MB, solutions = 5)							
16832	13408	-360.3564	681	-38.0000	-378.8563	8512516	896.99%
17110	13421	-347.1104	577	-38.0000	-378.7315	8526769	896.66%
17190	13641	-337.1913	715	-38.0000	-378.5983	8577198	896.31%
17403	13718	-266.2754	489	-38.0000	-378.5983	8642161	896.31%
17723	13869	-246.2897	615	-38.0000	-378.5983	8701973	896.31%
17846	14453	-147.7591	476	-38.0000	-378.5983	8901628	896.31%
18013	14743	-257.4287	619	-38.0000	-378.5983	9008331	896.31%
18451	14774	-193.0102	557	-38.0000	-378.5983	9013834	896.31%
18659	14808	-112.1777	501	-38.0000	-378.5983	9017455	896.31%
18954	15194	-365.5685	865	-38.0000	-378.5983	9123572	896.31%
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							
<u>Elapsed time = 682.61 sec.</u> (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							
<u>Elapsed time = 734.91 sec.</u> (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%
11							
<u>Elapsed time = 781.18 sec.</u> (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

```

3
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						
<b>21</b>							
<b>Nodes</b>	<b>Cuts/</b>						
<b>Node</b>	<b>Left</b>	<b>Objective</b>	<b>IInf</b>	<b>Best Integer</b>	<b>Best Bound</b>	<b>ItCnt</b>	<b>Gap</b>
34184	30011	infeasible		-39.0000	-377.1432	12462046	867.03%
<b>5</b>		<b>Elapsed time = 0.56 sec.</b> (7.69 ticks, tree = 1131.55 MB, solutions = 6)					
34185	30011	infeasible		-39.0000	-377.1432	12463576	867.03%
34186	30012	-353.1274	307	-39.0000	-377.1432	12467117	867.03%
34230	30050	-240.2890	140	-39.0000	-377.1432	12469248	867.03%
34284	30101	-96.2412	68	-39.0000	-377.1432	12469654	867.03%
34322	30026	-310.4203	254	-39.0000	-377.1432	12474494	867.03%
34358	30062	-208.3211	168	-39.0000	-377.1432	12474783	867.03%
34418	30117	-61.5243	49	-39.0000	-377.1432	12474986	867.03%
34429	30013	-375.1626	767	-39.0000	-377.1432	12465551	867.03%
34430	30013	-368.5689	712	-39.0000	-377.1432	12480749	867.03%
34467	30044	-274.8883	182	-39.0000	-377.1369	12485663	867.02%
<b>9</b>		<b>Elapsed time = 4.67 sec.</b> (3790.87 ticks, tree = 1118.48 MB, solutions = 6)					
34559	30016	-375.0799	850	-39.0000	-377.1369	12488423	867.02%
34566	30025	-347.9018	626	-39.0000	-376.9781	12489041	866.61%
34577	30032	-332.5967	607	-39.0000	-376.9781	12490820	866.61%
34601	30027	-337.4018	605	-39.0000	-376.9781	12498141	866.61%
34627	30041	-305.9294	499	-39.0000	-376.9781	12501938	866.61%
34686	30147	-296.6126	233	-39.0000	-376.9781	12501312	866.61%
34810	30028	-351.9984	446	-39.0000	-376.9781	12506723	866.61%
34871	30070	-210.9115	477	-39.0000	-376.9781	12496496	866.61%
34894	30030	-347.0129	721	-39.0000	-376.9781	12516063	866.61%
34921	30128	-340.5311	403	-39.0000	-376.9781	12501487	866.61%
<b>11</b>		<b>Elapsed time = 18.01 sec.</b> (13637.71 ticks, tree = 1129.36 MB, solutions = 6)					
35000	30164	-248.6996	190	-39.0000	-376.9781	12503763	866.61%
35127	30084	-205.3721	505	-39.0000	-376.9781	12522308	866.61%
35293	30114	-133.2772	471	-39.0000	-376.9781	12523058	866.61%
35359	30236	-342.9975	706	-39.0000	-376.9781	12518300	866.61%
35553	30295	-154.2894	114	-39.0000	-376.9781	12510201	866.61%
35761	30483	-66.1665	53	-39.0000	-376.9781	12512438	866.61%
35798	30258	-297.3622	651	-39.0000	-376.9781	12521841	866.61%
35816	30266	-281.3269	625	-39.0000	-376.9781	12523129	866.61%
35843	30276	-256.0856	595	-39.0000	-376.9744	12523344	866.60%

35885	30140	-302.2962	240	-39.0000	-376.9744	12517050	866.60%
5							
Elapsed time	= 30.67 sec.	(23289.65 ticks, tree	= 1133.67 MB, solutions	= 6)			
36002	30180	-252.7491	441	-39.0000	-376.9744	12529649	866.60%
36062	30299	-206.5953	589	-39.0000	-376.9744	12527129	866.60%
36101	30230	-57.4126	281	-39.0000	-376.9744	12532623	866.60%
36126	30319	-159.6736	546	-39.0000	-376.9744	12528123	866.60%
36145	30340	-344.3312	457	-39.0000	-376.9744	12533604	866.60%
36233	30409	-163.6412	356	-39.0000	-376.9744	12535025	866.60%
36303	30347	-91.1935	479	-39.0000	-376.9744	12529582	866.60%
36329	30235	-375.3955	857	-39.0000	-376.9744	12539899	866.60%
36545	30368	cutoff		-39.0000	-376.9744	12531654	866.60%
36575	30265	-348.5818	255	-39.0000	-376.9744	12541452	866.60%
5							
Elapsed time	= 42.20 sec.	(33038.41 ticks, tree	= 1127.58 MB, solutions	= 6)			
36709	30470	-351.3221	624	-39.0000	-376.9744	12544142	866.60%
36729	30559	-215.9049	649	-39.0000	-376.9744	12544298	866.60%
36812	30436	-161.8911	120	-39.0000	-376.9744	12548856	866.60%
36944	30486	-328.9821	597	-39.0000	-376.9744	12550670	866.60%
37174	30492	-322.6494	608	-39.0000	-376.9744	12552363	866.60%
37271	30718	-149.7022	112	-39.0000	-376.9744	12556065	866.60%
37335	30604	-117.6572	523	-39.0000	-376.9744	12548367	866.60%
37361	30612	-97.8061	497	-39.0000	-376.9744	12549204	866.60%
37508	30622	-74.8865	483	-39.0000	-376.9744	12549545	866.60%
37547	30284	-269.1983	676	-39.0000	-376.9744	12570795	866.60%
5							
Elapsed time	= 56.00 sec.	(42712.64 ticks, tree	= 1132.84 MB, solutions	= 6)			
37587	30639	-46.6761	404	-39.0000	-376.9744	12551100	866.60%
37639	30414	-311.7083	637	-39.0000	-376.9744	12561840	866.60%
37916	30226	-75.1134	38	-39.0000	-376.9744	12586701	866.60%
37975	30522	-298.5992	190	-39.0000	-376.9744	12567952	866.60%
38358	30734	-49.6809	34	-39.0000	-376.9744	12573259	866.60%
38425	30896	-312.8846	395	-39.0000	-376.9744	12576993	866.60%
38560	30651	-351.1738	707	-39.0000	-376.9744	12567726	866.60%
38703	30659	-338.3736	682	-39.0000	-376.9744	12569044	866.60%
38722	30923	-251.4943	422	-39.0000	-376.9744	12578618	866.60%
38807	30678	-300.9916	641	-39.0000	-376.9744	12570330	866.60%
Elapsed time	= 69.11 sec.	(52474.66 ticks, tree = 1168.75 MB, solutions = 6)					
38865	30114	-364.9152	785	-39.0000	-376.9744	12605868	866.60%
39094	30118	-364.5336	776	-39.0000	-376.9744	12608499	866.60%
39163	30390	-290.9313	188	-39.0000	-376.9744	12593666	866.60%
39318	30330	-128.7170	102	-39.0000	-376.9744	12608320	866.60%

39378 30824	-371.6508	666	-39.0000	-376.9744	12583385	866.60%
39448 30859	-235.6664	169	-39.0000	-376.9744	12587080	866.60%
39572 30207	-115.2196	106	-39.0000	-376.9744	12620071	866.60%
39664 30963	-184.5348	344	-39.0000	-376.9744	12600785	866.60%
39767 30781	-243.6394	154	-39.0000	-376.9744	12609310	866.60%
39849 30937	-367.9700	804	-39.0000	-376.9744	12597338	866.60%
5	<b>Elapsed time = 80.41 sec. (62223.15 ticks, tree = 1187.62 MB, solutions = 6)</b>					
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	<b>Elapsed time = 92.34 sec. (72321.10 ticks, tree = 1149.15 MB, solutions = 6)</b>					
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%
11	<b>Elapsed time = 104.01 sec. (81980.95 ticks, tree = 1160.34 MB, solutions = 6)</b>					
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%

```

5
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%
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)

-----
12 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

5 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%
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)						
<b>Nodefile size</b> = 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)						
<b>Nodefile size</b> = 505.19 MB (457.73 MB after compression)						
63986 56760	-361.2265	352	-40.0000	-376.5778	16863808	841.44%
* 64088+56788			-42.0000	-376.5778		796.61%
64161 56427	-308.4527	287	-42.0000	-376.5778	16861750	796.61%
64305 56426	-364.4031	448	-42.0000	-376.5778	16867050	796.61%
64344 56429	cutoff		-42.0000	-376.5778	16870294	796.61%
64408 56433	-361.1858	402	-42.0000	-376.5778	16864366	796.61%
64514 56592	-369.9594	867	-42.0000	-376.5778	16880737	796.61%
64661 56555	-117.7107	86	-42.0000	-376.5778	16881851	796.61%
64713 56603	-366.8417	779	-42.0000	-376.5778	16886930	796.61%
64780 56605	-366.4698	401	-42.0000	-376.5778	16885487	796.61%
64920 56444	-257.3129	304	-42.0000	-376.5778	16880818	796.61%
Elapsed time = 40.45 sec. (34952.40 ticks, tree = 2527.61 MB, solutions = 8)						
<b>Nodefile size</b> = 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%

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65319 56612    -366.8891 1013     -42.0000   -376.5778 16899193 796.61%
65328 56515    -369.2649  813     -42.0000   -376.5778 16898243 796.61%
65349 56619    -365.9130  961     -42.0000   -376.5778 16903443 796.61%
65377 56656    -374.9636  869     -42.0000   -376.5778 16903553 796.61%
65461 56566    -354.8815  435     -42.0000   -376.5778 16906832 796.61%
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%
2
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%

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67941 56855      -372.2216   428      -42.0000     -376.5778 16977830  796.61%
68103 56928      -331.4462   469      -42.0000     -376.5778 16990292  796.61%
Elapsed time = 85.79 sec. (75199.50 ticks, tree = 2566.21 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
68294 56955      -247.9800   326      -42.0000     -376.5778 16984262  796.61%
68361 56926      infeasible          -42.0000     -376.5778 16995251  796.61%
68454 56941      -342.9196   259      -42.0000     -376.5778 16998376  796.61%
68580 56992      -249.5999   176      -42.0000     -376.5778 17002343  796.61%
68785 57111      -334.3761   321      -42.0000     -376.5778 16998461  796.61%
68946 56636      -370.2219   1051     -42.0000     -376.5778 16959597  796.61%
68960 57248      infeasible          -42.0000     -376.5778 17004796  796.61%
69028 57254      infeasible          -42.0000     -376.5778 17007632  796.61%
69137 57046      cutoff                -42.0000     -376.5778 17011825  796.61%
69146 57258      -374.6623   732      -42.0000     -376.5778 17013586  796.61%
Elapsed time = 96.76 sec. (84893.06 ticks, tree = 2553.89 MB, solutions = 8)
Nodefile size = 505.19 MB (457.73 MB after compression)
69174 57079      -374.6247   714      -42.0000     -376.5778 17010021  796.61%
69379 57535      -154.2234   96       -42.0000     -376.5778 17040415  796.61%
69542 57048      -351.2630   495     -42.0000     -376.5778 17024459  796.61%
69611 57092      -249.8471   236     -42.0000     -376.5778 17027482  796.61%
69791 57123      -266.5293   180     -42.0000     -376.5778 17021100  796.61%
69896 57588      infeasible          -42.0000     -376.5778 17051599  796.61%
69900 57201      -372.7224   744     -42.0000     -376.5778 17026463  796.61%
69921 57253      -355.6185   324     -42.0000     -376.5778 17037474  796.61%
70000 57290      -294.2659   218     -42.0000     -376.5778 17038577  796.61%
70742 57498      -268.3576   172     -42.0000     -376.5778 17052046  796.61%
Elapsed time = 111.68 sec. (97530.70 ticks, tree = 2556.97 MB, solutions = 9)
Nodefile size = 505.19 MB (457.73 MB after compression)
71350 57728      -348.3798   248     -42.0000     -376.5778 17063553  796.61%
71743 57460      -373.4932   966     -42.0000     -376.5778 17049682  796.61%
71755 57653      -370.4464   636     -42.0000     -376.5778 17078692  796.61%
72187 57551      -215.6947   184     -42.0000     -376.5778 17066389  796.61%
72276 57850      -367.7073   661     -42.0000     -376.5778 17096223  796.61%
72618 57937      -157.8367   118     -42.0000     -376.5778 17107344  796.61%
73589 58103      -366.4535   645     -42.0000     -376.5778 17117318  796.61%
74114 58372      -220.1499   157     -42.0000     -376.5778 17127622  796.61%
74271 57688      -366.0440   1022    -42.0000     -376.5778 17107476  796.61%
74330 58468      -278.5357   406     -42.0000     -376.5778 17158803  796.61%
Elapsed time = 151.49 sec. (136817.80 ticks, tree = 2572.25 MB, solutions = 9)

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```

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)

Nodefile size = 505.19 MB (457.73 MB after compression)
 76625 58372      -276.7328   275      -42.0000     -376.5778 17215778 796.61%
 76896 58881      -363.3072   789      -42.0000     -376.5778 17266359 796.61%
 77088 58341      -205.9310   178      -42.0000     -376.5778 17178206 796.61%
 77452 58913      -289.3936   190      -42.0000     -376.5778 17282930 796.61%
 77896 58805      -59.1187    71      -42.0000     -376.5778 17249555 796.61%
 78198 58777      -104.5215   100      -42.0000     -376.5778 17202653 796.61%
 78213 58926      -368.4008   652      -42.0000     -376.5778 17267554 796.61%
 78401 58786      -372.5803   1028     -42.0000     -376.5778 17218675 796.61%
 78547 59186      -304.1862   222      -42.0000     -376.5778 17287687 796.61%
 78819 59304      -355.0582   246      -42.0000     -376.5778 17297787 796.61%
                                         2
Elapsed time = 213.20 sec. (216193.23 ticks, tree = 2715.45 MB, solutions = 11)

Nodefile size = 505.19 MB (457.73 MB after compression)
* 78861+59332           -43.0000     -376.5778      775.76%
 78863 58919      -372.1730   923      -43.0000     -376.5778 17245546 775.76%
 78865 58921      -362.0419   695      -43.0000     -376.5778 17262028 775.76%
 78908 58961      -287.4919   224      -43.0000     -376.5778 17274297 775.76%
 79046 59079      -351.1997   373      -43.0000     -376.5778 17285981 775.76%
 79251 59269      -136.6352   93       -43.0000     -376.5778 17296280 775.76%
 79485 59473      -331.8259   277      -43.0000     -376.5778 17304844 775.76%
 79610 59575      -368.4471   613      -43.0000     -376.5778 17311192 775.76%
 79779 59736      -235.4136   155      -43.0000     -376.5778 17320410 775.76%
 79874 59817      infeasible   -43.0000     -376.5778 17331372 775.76%
 79976 59913      -352.6447   359      -43.0000     -376.5778 17343498 775.76%
                                         2
Elapsed time = 240.73 sec. (260469.65 ticks, tree = 2807.01 MB, solutions = 12)

Nodefile size = 505.19 MB (457.73 MB after compression)
 80225 60135      -351.0370   334      -43.0000     -376.5778 17359520 775.76%

```

80482 60367	-372.6844	1128	-43.0000	-376.5778	17379949	775.76%
80486 60371	-370.6348	854	-43.0000	-376.5778	17391940	775.76%
80489 60374	-366.6817	652	-43.0000	-376.5778	17402505	775.76%
80618 60496	-366.6781	671	-43.0000	-376.5778	17414997	775.76%
80896 60756	cutoff		-43.0000	-376.5778	17426348	775.76%
81024 60865	-368.8018	769	-43.0000	-376.5778	17439191	775.76%
81161 60978	infeasible		-43.0000	-376.5778	17452029	775.76%
81372 61172	-368.2417	708	-43.0000	-376.5778	17463161	775.76%

```

GUB cover cuts applied: 916
3
@lique 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)

-----
12 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%
Elapsed time = 3.10 sec. (2384.36 ticks, tree = 3375.96 MB, solutions = 13)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
81438 71929 -351.7855 242     -43.0000    -376.3803 19472768 775.30%
81471 71961 -270.8111 173     -43.0000    -376.3803 19473216 775.30%
81515 72001 -157.5837 98      -43.0000    -376.3803 19473641 775.30%
81563 71926 -374.3382 753     -43.0000    -376.3803 19473609 775.30%
81564 71928 -372.4402 715     -43.0000    -376.3803 19481748 775.30%
81567 71930 -371.4346 663     -43.0000    -376.3803 19482880 775.30%
81571 71933 -371.2108 644     -43.0000    -376.3803 19483675 775.30%
81572 71934 -370.7107 636     -43.0000    -376.3803 19484433 775.30%
81576 71931 -360.4175 763     -43.0000    -376.3803 19502020 775.30%
81661 72012 -144.5408 107     -43.0000    -376.3803 19488685 775.30%
Elapsed time = 9.37 sec. (7373.28 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)

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Nodefile size = 1328.84 MB (1208.58 MB after compression)
85177 72284 -200.4956 128 -43.0000 -376.1368 19608089 774.74%
85252 72564 -366.6790 841 -43.0000 -376.1368 19577339 774.74%
85269 72536 infeasible -43.0000 -376.1368 19591276 774.74%
85318 72802 -272.0554 179 -43.0000 -376.1368 19598160 774.74%
85458 72106 -271.7240 204 -43.0000 -376.1368 19630436 774.74%
85583 72343 -369.7473 635 -43.0000 -376.1368 19620884 774.74%
85753 72537 -368.2100 867 -43.0000 -376.1368 19598411 774.74%
85869 72101 -319.9908 214 -43.0000 -376.1368 19628379 774.74%
86144 72573 -271.7490 196 -43.0000 -376.1368 19604341 774.74%
86291 72116 -306.6315 350 -43.0000 -376.1368 19628397 774.74%
5
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%
11							
Elapsed time = 107.23 sec. (88918.59 ticks, tree = 3355.42 MB, solutions = 13)							
Nodefile size = 1328.84 MB (1208.58 MB after compression)							
90747	73000	-232.2603	144	-43.0000	-376.1368	19670487	774.74%
90865	73685	-212.0829	144	-43.0000	-376.1368	19685798	774.74%
91021	73711	-147.6431	128	-43.0000	-376.1368	19686698	774.74%
91106	73041	-279.0274	184	-43.0000	-376.1368	19662197	774.74%
91217	72694	-367.0982	639	-43.0000	-376.1368	19714979	774.74%
91226	72696	-364.1187	634	-43.0000	-376.1368	19718381	774.74%
91279	73087	-334.1832	285	-43.0000	-376.1368	19684478	774.74%
91581	72886	-239.2958	177	-43.0000	-376.1368	19731529	774.74%
91880	72773	-172.1287	147	-43.0000	-376.1368	19724728	774.74%
92103	72979	-318.1041	204	-43.0000	-376.1368	19741671	774.74%
5							
Elapsed time = 122.50 sec. (101620.07 ticks, tree = 3349.38 MB, solutions = 13)							
Nodefile size = 1328.84 MB (1208.58 MB after compression)							
92488	73193	-370.3096	645	-43.0000	-376.1368	19705612	774.74%
92693	73253	-263.1795	257	-43.0000	-376.1368	19716357	774.74%
93074	72883	-356.9105	851	-43.0000	-376.1368	19744324	774.74%
93449	72909	-298.8729	213	-43.0000	-376.1368	19753841	774.74%
94224	73670	-245.3925	164	-43.0000	-376.1368	19727039	774.74%
95151	73027	-142.9352	102	-43.0000	-376.1368	19773585	774.74%
96004	73918	-234.3377	168	-43.0000	-376.1368	19744955	774.74%
96537	75077	-76.1794	41	-43.0000	-376.1368	19787753	774.74%
97188	73361	-339.1905	244	-43.0000	-376.1368	19803446	774.74%
97957	73408	-98.3815	50	-43.0000	-376.1368	19811535	774.74%
Elapsed time = 169.17 sec. (140231.77 ticks, tree = 3363.58 MB, solutions = 13)							
Nodefile size = 1328.84 MB (1208.58 MB after compression)							
98359	73123	-368.1863	739	-43.0000	-376.1368	19803156	774.74%
99166	73425	-362.4546	512	-43.0000	-376.1368	19828990	774.74%
99573	74050	-348.9752	262	-43.0000	-376.1368	19832253	774.74%
*100206+75506				-44.0000	-376.1368		754.86%
100260	74255	-187.1122	111	-44.0000	-376.1368	19841225	754.86%

```

100755 73923 -141.6525    76   -44.0000   -376.1368 19855053  754.86%
101360 74183 -254.1317   165   -44.0000   -376.1368 19869790  754.86%
101983 74396 -365.9683   679   -44.0000   -376.1368 19880718  754.86%
102256 73251 -358.7644   844   -44.0000   -376.1368 19850813  754.86%
102534 74551 -369.3515   969   -44.0000   -376.1368 19886540  754.86%
102636 74685 -201.0157   189   -44.0000   -376.1368 19906540  754.86%
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%
23 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%
2 Elapsed time = 386.93 sec. (378266.74 ticks, tree = 3689.23 MB, solutions = 18)
Nodefile size = 1328.84 MB (1208.58 MB after compression)
123606 77360 -367.9078 813 -44.0000 -376.1368 20304015 754.86%
123789 77402 -270.6668 213 -44.0000 -376.1368 20313171 754.86%
124252 77565 -147.9091 111 -44.0000 -376.1368 20322273 754.86%
124710 80275 -339.1575 259 -44.0000 -376.1368 20399552 754.86%
125071 80455 -130.4602 96 -44.0000 -376.1368 20407189 754.86%
125120 80488 -364.5023 979 -44.0000 -376.1368 20414180 754.86%
125393 78074 -67.5268 51 -44.0000 -376.1368 20356949 754.86%
125548 78206 -61.4737 25 -44.0000 -376.1368 20365875 754.86%
125824 80617 -365.8242 646 -44.0000 -376.1368 20434361 754.86%
126311 80820 -149.0581 106 -44.0000 -376.1368 20445898 754.86%

```

```

Elapsed time = 402.92 sec. (417930.32 ticks, tree = 3750.55 MB, solutions = 18)
9
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)
```

```
12 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%
					9		
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      -44.0000    -375.9064 24887689 754.33%
9
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%

```

```

2 Elapsed time = 44.97 sec. (35418.05 ticks, tree = 4934.31 MB, solutions = 20)
Nodefile size = 2828.82 MB (2551.19 MB after compression)
135026 115538 -238.0279 154 -44.0000 -375.6031 24941038 753.64%
135204 115612 -369.4843 771 -44.0000 -375.6031 24941848 753.64%
135514 116263 -248.8541 173 -44.0000 -375.6031 24945872 753.64%
135735 115696 -158.7882 110 -44.0000 -375.6031 24946026 753.64%
135885 116414 -164.6318 107 -44.0000 -375.6031 24949736 753.64%
136157 115950 -98.4789 83 -44.0000 -375.6031 24954128 753.64%
136177 116049 -371.4216 844 -44.0000 -375.6031 24942096 753.64%
136184 115729 -359.2447 647 -44.0000 -375.6031 24956224 753.64%
136316 116080 -98.6373 67 -44.0000 -375.6031 24961109 753.64%
136393 116100 -349.1181 249 -44.0000 -375.6031 24963534 753.64%
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%
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%
					9		
Elapsed time = 171.10 sec. (136215.45 ticks, tree = 5020.68 MB, solutions = 20)							
Nodefile size = 2828.82 MB (2551.19 MB after compression)							
153265	117421	-131.6317	86	-44.0000	-375.5297	25148312	753.48%
153651	123366	-204.8835	135	-44.0000	-375.5297	25710075	753.48%
154291	127032	-273.1402	193	-44.0000	-375.4562	26185133	753.31%
154685	132699	-230.5562	138	-44.0000	-375.4562	26809062	753.31%
155410	135455	-86.7902	48	-44.0000	-375.0224	27113648	752.32%
156010	135713	-353.6035	369	-44.0000	-374.9424	27159569	752.14%
156428	136562	-373.1474	752	-44.0000	-374.9424	27240959	752.14%
156856	136991	-207.2019	119	-44.0000	-374.9424	27278840	752.14%
157325	137622	-282.8151	202	-44.0000	-374.6467	27376398	751.47%
157554	137746	-361.1068	365	-44.0000	-374.6467	27400626	751.47%
115							
Elapsed time = 229.01 sec. (174835.59 ticks, tree = 6750.00 MB, solutions = 20)							
Nodefile size = 4694.67 MB (4271.79 MB after compression)							
158142	137958	-121.8675	82	-44.0000	-374.6467	27423219	751.47%
158452	138468	-76.5513	58	-44.0000	-374.3973	27479789	750.90%
158893	138456	-347.6235	270	-44.0000	-374.3973	27513832	750.90%
159308	139453	-83.8846	50	-44.0000	-374.3973	27639581	750.90%
159480	139089	-351.9897	348	-44.0000	-374.2840	27601366	750.65%
159932	140136	-288.8156	190	-44.0000	-374.2840	27773711	750.65%
160342	139970	-351.9906	293	-44.0000	-374.2840	27751169	750.65%
161057	140601	-366.0149	640	-44.0000	-374.2840	27867684	750.65%
162160	140791	-223.6580	127	-44.0000	-374.2101	27879510	750.48%
163097	142224	-222.4034	148	-44.0000	-374.1965	28026597	750.45%
5							
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%
2 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%
2 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%
2 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%

```

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2 Elapsed time = 486.25 sec. (367163.04 ticks, tree = 7512.82 MB, solutions = 20)
Nodefile size = 5447.40 MB (4922.11 MB after compression)
189644 164386 -367.8376 887 -44.0000 -373.3443 30477271 748.51%
190685 164981 -87.2124 61 -44.0000 -373.3443 30514247 748.51%
191184 166418 -333.6920 221 -44.0000 -373.3443 30646990 748.51%
192458 166950 -208.3170 120 -44.0000 -373.3443 30699405 748.51%
193547 167529 -198.3154 118 -44.0000 -373.3443 30739547 748.51%
194774 168011 -168.6088 199 -44.0000 -373.2787 30794964 748.36%
195925 168908 -142.5090 148 -44.0000 -373.2427 30835364 748.28%
196620 171308 -224.7571 158 -44.0000 -373.2408 30997697 748.27%
197264 171376 -371.6623 716 -44.0000 -373.2408 31005841 748.27%
198034 171635 -208.1538 134 -44.0000 -373.2055 31055553 748.19%
9 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%
2 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%
2 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%

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212919 185068 -288.2498 184 -44.0000 -372.8748 32431657 747.44%
214028 185646 -210.1929 142 -44.0000 -372.8748 32487431 747.44%
214899 185756 -200.4004 137 -44.0000 -372.8600 32475142 747.41%
215323 186568 -146.7879 101 -44.0000 -372.8563 32572067 747.40%
215585 186646 -265.0594 174 -44.0000 -372.8430 32582774 747.37%
215930 186866 -296.3604 233 -44.0000 -372.8430 32646715 747.37%
216342 188005 -368.3260 1030 -44.0000 -372.8430 32726916 747.37%
216864 188736 -183.1399 110 -44.0000 -372.8430 32848795 747.37%
217090 189090 -331.5462 245 -44.0000 -372.8430 32903193 747.37%
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%
Elapsed time = 804.93 sec. (599059.75 ticks, tree = 9113.38 MB, solutions = 20)
Nodefile size = 7058.01 MB (6351.40 MB after compression)

231216 200588 -358.3446 489 -44.0000 -372.5531 34129659 746.71%
231583 200216 -268.3678 255 -44.0000 -372.5531 34115070 746.71%
232305 201798 -46.5832 26 -44.0000 -372.5531 34219507 746.71%
233137 202370 -185.0193 120 -44.0000 -372.5031 34307455 746.60%

```

234418	201984	-225.0413	192	-44.0000	-372.4962	34280003	746.58%
235315	203798	-343.5671	300	-44.0000	-372.4823	34427805	746.55%
235540	203201	-194.1673	132	-44.0000	-372.4823	34396450	746.55%
236303	204300	-90.3678	54	-44.0000	-372.4732	34472118	746.53%
236745	204491	-353.6942	922	-44.0000	-372.4732	34519696	746.53%
237725	205433	-362.9104	718	-44.0000	-372.4587	34591948	746.50%
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%

9  
Performing restart 2

```

Repeating presolve.
Tried aggregator 1 time.
Reduced MIP has 3556 rows, 5459 columns, and 23781 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (12.05 ticks)

Tried aggregator 1 time.
Reduced MIP has 3556 rows, 5459 columns, and 23781 nonzeros.
Reduced MIP has 4603 binaries, 51 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (16.72 ticks)

Resovle 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%
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							
<b>Elapsed time = 1202.91 sec.</b> (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%
<b>Elapsed time = 1250.04 sec.</b> (972969.48 ticks, tree = 103.61 MB, solutions = 20)							
253990	2793	-354.1329	866	-44.0000	-372.1916	38772365	745.89%
254125	2847	-378.1667	932	-44.0000	-372.1916	38821293	745.89%
254160	3057	-345.8537	710	-44.0000	-372.1916	38991676	745.89%
254272	3174	-338.3096	397	-44.0000	-372.1916	39057856	745.89%
254829	3402	-355.6737	381	-44.0000	-372.1916	39162730	745.89%
255039	3352	-378.1796	878	-44.0000	-372.1916	39140890	745.89%
255759	3966	-377.3962	848	-44.0000	-372.1916	39289058	745.89%
256132	4683	-376.0871	913	-44.0000	-372.1916	39411724	745.89%
256571	4897	-110.1847	135	-44.0000	-372.1916	39448784	745.89%
256899	5006	-264.7572	206	-44.0000	-372.1916	39493263	745.89%
5							
<b>Elapsed time = 1299.80 sec.</b> (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%
5 Elapsed time = 1345.55 sec. (1050174.00 ticks, tree = 360.71 MB, solutions = 20)
262463 9727 -346.0636 360 -44.0000 -372.1916 40305990 745.89%
262827 10015 -53.0047 53 -44.0000 -372.1916 40336812 745.89%
263497 10204 -291.6292 329 -44.0000 -372.1916 40409727 745.89%
263810 10834 -368.7024 900 -44.0000 -372.1916 40508382 745.89%
264034 11380 -299.6250 270 -44.0000 -372.1916 40589629 745.89%
264353 11408 -333.6570 364 -44.0000 -372.1916 40631990 745.89%
265209 11627 -127.5949 81 -44.0000 -372.1916 40690974 745.89%
265375 12058 -373.9214 775 -44.0000 -372.1916 40825316 745.89%
265683 12067 -374.6869 871 -44.0000 -372.1916 40813199 745.89%
266145 12871 -108.7038 66 -44.0000 -372.1916 40958008 745.89%
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%
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%
5							
<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%
296765	36460	-354.9554	528	-44.0000	-371.2083	44019420	743.66%
5							
<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%
5							
<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%
5							
<b>Elapsed time = 1741.50 sec.</b> (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%
140							
<b>Elapsed time = 1792.12 sec.</b> (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>Elapsed time = 1844.27 sec.</b> (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%

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317677 51183    -365.7037  1061    -44.0000   -369.6668 46348889  740.15%
318344 51962    -125.6950   92      -44.0000   -369.6668 46450552  740.15%
318572 51990    -368.0280  694     -44.0000   -369.6179 46457249  740.04%
318765 52695    -357.1016  1077    -44.0000   -369.5690 46541748  739.93%
319126 52963    -352.8065  686     -44.0000   -369.5690 46586748  739.93%
319440 53430    -260.1408  161     -44.0000   -369.5690 46663375  739.93%
Elapsed time = 1896.37 sec. (1479194.25 ticks, tree = 1951.39 MB, solutions = 20)
320144 53982    -234.4145  165     -44.0000   -369.5411 46755129  739.87%
320530 53857    -207.5893  175     -44.0000   -369.5411 46726581  739.87%
320617 53926    -344.9031  756     -44.0000   -369.5411 46789304  739.87%
321019 54333    -331.2943  278     -44.0000   -369.5411 46876025  739.87%
321384 54728    -330.9338  393     -44.0000   -369.4818 46956127  739.73%
Began writing nodes to disk (directory ./cpx6hXQcQ created)
321929 55231    -205.4632  119     -44.0000   -369.4596 47068125  739.68%
322419 55580    -324.8614  213     -44.0000   -369.4596 47114860  739.68%
322789 55897    -364.3820  405     -44.0000   -369.3454 47171636  739.42%
323522 56158    -364.5998  889     -44.0000   -369.3454 47201561  739.42%
323533 56166    -341.7744  430     -44.0000   -369.3454 47208791  739.42%
Elapsed time = 1948.33 sec. (1518462.54 ticks, tree = 2111.35 MB, solutions = 20)
Nodefile size = 58.62 MB (51.63 MB after compression)
323942 57003    -96.3349  92      -44.0000   -369.3155 47332465  739.35%
324164 57093    -340.3201  295     -44.0000   -369.3155 47380106  739.35%
324358 57091    -342.8492  664     -44.0000   -369.3155 47399665  739.35%
324721 57452    -332.6673  256     -44.0000   -369.3155 47485341  739.35%
325593 57417    -80.5629  105     -44.0000   -369.2700 47458323  739.25%
325870 57756    -344.9406  339     -44.0000   -369.2662 47566012  739.24%
326635 58368    -235.1431  177     -44.0000   -369.2522 47647462  739.21%
326735 58498    -310.1259  223     -44.0000   -369.2522 47686593  739.21%
327241 58889    -332.4587  307     -44.0000   -369.2522 47744689  739.21%
328157 58732    -348.2701  337     -44.0000   -369.2483 47714755  739.20%
Elapsed time = 2000.08 sec. (1556813.49 ticks, tree = 2191.10 MB, solutions = 20)
Nodefile size = 138.10 MB (121.57 MB after compression)
328696 59366    -349.9339  591     -44.0000   -369.2483 47866301  739.20%
329258 59928    -200.9429  112     -44.0000   -369.2483 47903916  739.20%
330085 59816    -360.8325  274     -44.0000   -369.2169 47888319  739.13%
330696 60569    -251.8809  167     -44.0000   -369.1513 47944891  738.98%
331215 61510    -350.2743  253     -44.0000   -369.1513 48067414  738.98%
331643 61684    -252.4282  148     -44.0000   -369.1169 48074972  738.90%
332328 62542    -300.0368  269     -44.0000   -369.1169 48153942  738.90%

```

333052	62613	-172.4415	137	-44.0000	-369.1169	48170227	738.90%
333503	63456	-273.7816	225	-44.0000	-369.0920	48254726	738.85%
334319	64313	-129.4382	75	-44.0000	-369.0066	48319508	738.65%
9							
Elapsed time = 2053.05 sec. (1595009.26 ticks, tree = 2609.90 MB, solutions = 20)							
<b>Nodefile size = 546.80 MB (482.47 MB after compression)</b>							
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%
9							
Elapsed time = 2105.71 sec. (1633306.25 ticks, tree = 2773.62 MB, solutions = 20)							
<b>Nodefile size = 694.67 MB (612.65 MB after compression)</b>							
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%
2							
Elapsed time = 2158.28 sec. (1671605.97 ticks, tree = 3247.77 MB, solutions = 20)							
<b>Nodefile size = 1193.67 MB (1058.69 MB after compression)</b>							
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)
9
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)

-----  
12 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%
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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%
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352961	78441	-368.1422	467	-46.0000	-368.3667	50059688	700.80%
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352963	78442	-366.8929	459	-46.0000	-368.3667	50061062	700.80%
--------	-------	-----------	-----	----------	-----------	----------	---------

352970	78443	-364.4998	478	-46.0000	-368.3667	50063349	700.80%
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352991	78459	-359.1808	287	-46.0000	-368.3667	50061782	700.80%
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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%
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354172	78670	-225.7101	139	-46.0000	-368.3065	50075904	700.67%
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354385	78504	-226.4890	127	-46.0000	-368.2929	50093543	700.64%
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354717	78838	-68.3427	35	-46.0000	-368.2929	50076924	700.64%
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354895	78735	-366.5307	385	-46.0000	-368.2929	50081410	700.64%
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355013	78725	-358.3571	260	-46.0000	-368.2929	50081358	700.64%
--------	-------	-----------	-----	----------	-----------	----------	---------

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Elapsed time = 18.04 sec. (13079.83 ticks, tree = 3596.11 MB, solutions = 21)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
355350 78840 -106.1301 61 -46.0000 -368.2929 50082313 700.64%
355421 78637 -265.3412 275 -46.0000 -368.2929 50101647 700.64%
355525 78674 -185.2515 141 -46.0000 -368.2802 50103370 700.61%
*355558+78900 -47.0000 -368.2802 683.57%
355620 78594 -339.7121 378 -47.0000 -368.2802 50098468 683.57%
355766 78770 -294.4367 166 -47.0000 -368.2802 50106522 683.57%
356139 78635 -175.6360 123 -47.0000 -368.2802 50098267 683.57%
356248 78595 -327.9391 290 -47.0000 -368.2802 50116071 683.57%
356341 78649 -216.7224 142 -47.0000 -368.2802 50118193 683.57%
356578 78816 -170.0356 106 -47.0000 -368.2802 50108680 683.57%
356638 78453 -344.8623 449 -47.0000 -368.2802 50116537 683.57%
Elapsed time = 29.93 sec. (23092.66 ticks, tree = 3533.95 MB, solutions = 24)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
356671 78466 -341.4183 357 -47.0000 -368.2802 50117958 683.57%
356751 78750 -256.5897 150 -47.0000 -368.2802 50111786 683.57%
356870 78469 -366.3548 433 -47.0000 -368.2802 50121648 683.57%
356949 78525 -255.7729 163 -47.0000 -368.2802 50124119 683.57%
357102 78851 -349.7279 232 -47.0000 -368.2802 50117120 683.57%
*357191+78873 -48.0000 -368.2802 667.25%
357191 78711 -367.6334 1100 -48.0000 -368.2802 50124118 667.25%
357194 78714 -367.6270 1104 -48.0000 -368.2802 50124781 667.25%
357195 78609 -342.4514 413 -48.0000 -368.2802 50139710 667.25%
357262 78665 -248.5754 138 -48.0000 -368.2802 50141684 667.25%
357380 78718 -354.8980 803 -48.0000 -368.2802 50142887 667.25%
Elapsed time = 44.43 sec. (43023.32 ticks, tree = 3542.02 MB, solutions = 27)
Nodefile size = 1531.15 MB (1354.94 MB after compression)
357385 78720 -354.1313 745 -48.0000 -368.2802 50144502 667.25%
357389 78723 -352.5103 493 -48.0000 -368.2802 50146723 667.25%
357394 78727 -339.5890 283 -48.0000 -368.2802 50148761 667.25%
357420 78744 -332.3197 331 -48.0000 -368.2802 50149654 667.25%
357451 78769 -280.8813 168 -48.0000 -368.2802 50150722 667.25%
357488 78795 -215.9856 158 -48.0000 -368.2802 50151746 667.25%
357527 78746 -354.7789 1031 -48.0000 -368.2802 50162814 667.25%
357530 78749 -354.6699 1031 -48.0000 -368.2802 50163649 667.25%
357531 78750 -346.2256 653 -48.0000 -368.2802 50170449 667.25%
357533 78752 -344.5490 744 -48.0000 -368.2802 50171923 667.25%
Elapsed time = 55.57 sec. (57967.17 ticks, tree = 3535.25 MB, solutions = 27)

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Nodefile size = 1531.15 MB (1354.94 MB after compression)
357536 78821 -366.0749 1161 -48.0000 -368.2802 50157991 667.25%
357540 78823 -366.0599 1158 -48.0000 -368.2802 50158619 667.25%
357556 78769 -325.5245 302 -48.0000 -368.2802 50177346 667.25%
357590 78792 -291.4648 232 -48.0000 -368.2802 50178499 667.25%
357621 78817 -233.7738 198 -48.0000 -368.2802 50179962 667.25%
357636 78824 -365.1710 595 -48.0000 -368.2802 50183101 667.25%
357669 78849 -340.1584 284 -48.0000 -368.2802 50185185 667.25%
357722 78826 -361.9055 1039 -48.0000 -368.2802 50168111 667.25%
357723 78827 -354.3601 752 -48.0000 -368.2802 50176673 667.25%
357725 78829 -352.8350 745 -48.0000 -368.2802 50178651 667.25%
Elapsed time = 63.73 sec. (73838.94 ticks, tree = 3542.48 MB, solutions = 28)

Nodefile size = 1531.15 MB (1354.94 MB after compression)
357727 78831 -351.3868 663 -48.0000 -368.2802 50180601 667.25%
357729 78833 -349.5185 509 -48.0000 -368.2802 50182598 667.25%
357733 78835 -339.0805 430 -48.0000 -368.2802 50184554 667.25%
357757 78857 -321.4356 295 -48.0000 -368.2802 50185975 667.25%
357781 78864 -367.4109 559 -48.0000 -368.2802 50189238 667.25%
357788 78868 -362.7362 469 -48.0000 -368.2802 50191101 667.25%
357803 78879 -356.6581 374 -48.0000 -368.2802 50192864 667.25%

GUB cover cuts applied: 1515
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)

```

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-----
Iteration 11
Bounds on # of cuts = 8 with [3 3 2]
Error = 52 (out of 100 instances)
Accuracy = 48
Solving time = 1.180936951 min (minutes)
Accumulated time = 69.380926815 min (minutes)

Solution status code = 104
LB on error = -268.191364056
Relative objective gap = 6.670653418

Selected variables:
A_AGE (Continuous)
PEMLR (Categorical)

Number of selected variables = 2 (1 continuous + 1 categorical)
-----
12
version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
CPXPARAM_MIP_Strategy_File 3
CPXPARAM_MIP_Limits_Solutions 1
CPXPARAM_TimeLimit 82237.144391113281
CPXPARAM_MIP_Limits_TreeMemory 204800

21
Nodes Cuts/
Node Left Objective IInf Best Integer Best Bound ItCnt Gap
357813 81848 infeasible -48.0000 -368.1914 50513898 667.07%
2
Elapsed time = 0.66 sec. (292.33 ticks, tree = 3726.48 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
357826 81861 -292.1446 183 -48.0000 -368.1914 50513559 667.07%
357851 81885 -234.4599 151 -48.0000 -368.1914 50514204 667.07%
357887 81913 -152.0224 89 -48.0000 -368.1909 50514540 667.06%
357920 81854 -357.2824 437 -48.0000 -368.1909 50516152 667.06%
357957 81858 -352.0901 310 -48.0000 -368.1909 50519329 667.06%
358005 81876 -328.8730 208 -48.0000 -368.1909 50519839 667.06%
358061 81952 -365.6237 549 -48.0000 -368.1909 50516426 667.06%
358123 81944 -173.5007 110 -48.0000 -368.1909 50520624 667.06%

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358187 81986      -63.5680    31     -48.0000      -368.1909 50520867 667.06%
358404 81869      -356.0177   335     -48.0000      -368.1843 50525639 667.05%
Elapsed time = 4.90 sec. (3429.12 ticks, tree = 3706.40 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
358736 81977      -104.3151   66     -48.0000      -368.1843 50527782 667.05%
359077 81930      -213.6064   155     -48.0000      -368.1843 50539357 667.05%
359402 81958      -126.7440   131     -48.0000      -368.1843 50534882 667.05%
359558 82114      -323.8779   203     -48.0000      -368.1843 50527920 667.05%
360011 82123      -110.9767   62     -48.0000      -368.1843 50534255 667.05%
360279 82251      -303.4537   198     -48.0000      -368.1843 50531448 667.05%
360674 82270      -333.9872   256     -48.0000      -368.1843 50533165 667.05%
360773 82324      -216.5179   149     -48.0000      -368.1433 50535459 666.97%
360935 81876      -334.8739   394     -48.0000      -368.1433 50554007 666.97%
361126 82233      -126.4382   85     -48.0000      -368.1433 50538997 666.97%
Elapsed time = 16.84 sec. (13063.54 ticks, tree = 3721.75 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
361224 82365      -356.3953   443     -48.0000      -368.1433 50542559 666.97%
361281 82131      -357.4859   303     -48.0000      -368.1433 50550840 666.97%
361426 82156      -326.2501   224     -48.0000      -368.1433 50553536 666.97%
361646 82220      -176.9277   120     -48.0000      -368.1433 50556001 666.97%
361770 82452      -180.0865   199     -48.0000      -368.1433 50554805 666.97%
361955 82503      -57.9050    56     -48.0000      -368.1433 50556571 666.97%
362344 82097      -142.5888   80     -48.0000      -368.1433 50569144 666.97%
362616 82168      -298.4494   201     -48.0000      -368.1433 50555327 666.97%
362791 82238      -120.0840   76     -48.0000      -368.1433 50557846 666.97%
363008 82410      -348.3597   333     -48.0000      -368.1433 50568317 666.97%
Elapsed time = 29.19 sec. (22675.86 ticks, tree = 3702.14 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
363419 82370      -120.3047   72     -48.0000      -368.1433 50561564 666.97%
363578 82189      -249.4025   251     -48.0000      -368.1433 50581892 666.97%
363716 82216      -192.8838   220     -48.0000      -368.1433 50583993 666.97%
364045 82643      -113.9610   77     -48.0000      -368.1433 50563974 666.97%
364090 82681      -358.5332   390     -48.0000      -368.1433 50576810 666.97%
364122 82699      -341.6880   311     -48.0000      -368.1433 50578930 666.97%
364284 82291      -317.6356   231     -48.0000      -368.1433 50591814 666.97%
364631 82674      -357.5447   338     -48.0000      -368.1433 50572614 666.97%
364749 82708      -296.0979   196     -48.0000      -368.1433 50574904 666.97%
364984 82786      -87.9932   99     -48.0000      -368.1433 50575721 666.97%
Elapsed time = 41.83 sec. (32254.33 ticks, tree = 3717.44 MB, solutions = 29)

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Nodefile size = 1679.11 MB (1484.78 MB after compression)
365223 82504 -191.5209 217 -48.0000 -368.1433 50591049 666.97%
365504 82549 -331.3050 208 -48.0000 -368.1433 50601365 666.97%
365992 82893 -127.0245 73 -48.0000 -368.1433 50588165 666.97%
366170 82544 -366.6969 623 -48.0000 -368.1433 50597281 666.97%
366176 82548 -355.5594 469 -48.0000 -368.1433 50601349 666.97%
366189 82559 -351.7782 427 -48.0000 -368.1433 50603729 666.97%
366204 82569 -339.4731 368 -48.0000 -368.1433 50607134 666.97%
366249 82599 -272.1125 282 -48.0000 -368.1433 50608232 666.97%
366396 82671 -114.3516 71 -48.0000 -368.1433 50609897 666.97%
366634 82736 -309.9270 209 -48.0000 -368.1433 50611201 666.97%
Elapsed time = 54.67 sec. (42460.70 ticks, tree = 3710.17 MB, solutions = 29)

Nodefile size = 1679.11 MB (1484.78 MB after compression)
366756 82821 -111.5596 54 -48.0000 -368.1433 50612395 666.97%
366807 82858 -343.9349 258 -48.0000 -368.1433 50613675 666.97%
366896 82914 -211.1564 174 -48.0000 -368.1433 50615760 666.97%
366985 82971 -366.4920 430 -48.0000 -368.1433 50617063 666.97%
367034 82400 -351.3165 559 -48.0000 -368.1433 50587667 666.97%
367120 83037 -244.8728 179 -48.0000 -368.1433 50620481 666.97%
367337 82703 -334.1119 233 -48.0000 -368.1433 50628475 666.97%
367706 82986 -316.4094 188 -48.0000 -368.1433 50617616 666.97%
367821 83126 -356.0752 340 -48.0000 -368.1433 50627458 666.97%
368044 82503 -135.1360 111 -48.0000 -368.1433 50593666 666.97%
Elapsed time = 67.00 sec. (52139.75 ticks, tree = 3695.91 MB, solutions = 29)

Nodefile size = 1679.11 MB (1484.78 MB after compression)
368238 82922 -164.7335 92 -48.0000 -368.1433 50634114 666.97%
368430 83224 -123.8483 141 -48.0000 -368.1433 50637485 666.97%
368773 83201 -128.9948 87 -48.0000 -368.1433 50629760 666.97%
368913 83264 -357.5110 311 -48.0000 -368.1433 50641918 666.97%
369098 83112 -324.3748 198 -48.0000 -368.1433 50639612 666.97%
369400 83329 -191.7452 204 -48.0000 -368.1433 50645762 666.97%
369572 83433 -223.7018 132 -48.0000 -368.1433 50636921 666.97%
369806 82380 -287.5304 169 -48.0000 -368.1433 50648326 666.97%
370042 83155 -230.0538 152 -48.0000 -368.1433 50627192 666.97%
370296 83206 -105.6802 84 -48.0000 -368.1433 50627997 666.97%
Elapsed time = 79.67 sec. (61734.30 ticks, tree = 3719.22 MB, solutions = 29)

Nodefile size = 1679.11 MB (1484.78 MB after compression)
370473 83648 -363.5100 330 -48.0000 -368.1433 50644687 666.97%
370572 83690 -301.8013 207 -48.0000 -368.1433 50648101 666.97%

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370729 83483   -197.3347  130    -48.0000   -368.1387 50658662  666.96%
370929 83541   -365.7080  488    -48.0000   -368.1387 50660523  666.96%
371088 83221   -351.9229  387    -48.0000   -368.1387 50653084  666.96%
371487 83670   -73.6233   44     -48.0000   -368.1387 50663896  666.96%
371836 83297   -205.4547  120    -48.0000   -368.1387 50656731  666.96%
371955 84037   -363.3737  398    -48.0000   -368.1387 50658794  666.96%
372245 84150   -104.1935  62     -48.0000   -368.1387 50660639  666.96%
372599 84174   -356.4815  416    -48.0000   -368.1387 50662713  666.96%
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%
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%

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384080 83309   -101.5742    51    -48.0000    -368.1295 50766747  666.94%
384963 83446   -105.2105    49    -48.0000    -368.1295 50774019  666.94%
386015 84519   -346.9758   297    -48.0000    -368.1265 50783476  666.93%
386910 85693   -155.1845   151    -48.0000    -368.1265 50775095  666.93%
387595 84934   -333.2850   217    -48.0000    -368.1265 50794129  666.93%
Elapsed time = 167.93 sec. (131619.11 ticks, tree = 3741.29 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
388775 86007   -55.9050    38    -48.0000    -368.1265 50790936  666.93%
389667 89849   -58.8835    63    -48.0000    -368.1265 51217466  666.93%
390428 84259   -235.6584   138    -48.0000    -368.1265 50820389  666.93%
391907 85686   -200.5898   122    -48.0000    -368.1265 50817259  666.93%
393428 86618   -190.2522   146    -48.0000    -368.1265 51023481  666.93%
394894 85686   -338.0291   262    -48.0000    -368.1265 50892802  666.93%
396235 86317   -283.0987   189    -48.0000    -368.1265 50835383  666.93%
397505 86197   -70.7395    64    -48.0000    -368.1265 50901768  666.93%
398333 86550   -347.5027   457    -48.0000    -368.1265 50846264  666.93%
399245 86427   -177.6206   95    -48.0000    -368.1265 50911461  666.93%
Elapsed time = 217.63 sec. (169797.21 ticks, tree = 3979.15 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
400219 86967   -365.8791   488    -48.0000    -368.1265 50855776  666.93%
401660 91267   -243.3707   155    -48.0000    -368.1265 51274192  666.93%
403296 87512   -341.1402   231    -48.0000    -368.1265 50866250  666.93%
404989 84983   -140.2182   86     -48.0000    -368.0929 50859564  666.86%
406525 88101   -184.9819   105    -48.0000    -368.0929 50876062  666.86%
407805 92086   -259.9844   159    -48.0000    -368.0929 51296163  666.86%
409441 86511   -258.7671   146    -48.0000    -368.0929 50913194  666.86%
411560 92832   -360.5152   318    -48.0000    -368.0929 51306048  666.86%
413551 93075   -71.0918    41    -48.0000    -368.0929 51311387  666.86%
415320 93351   -366.3324   416    -48.0000    -368.0856 51316812  666.84%
Elapsed time = 280.95 sec. (207992.61 ticks, tree = 4136.27 MB, solutions = 29)
Nodefile size = 1679.11 MB (1484.78 MB after compression)
416761 93635   -356.6959   307    -48.0000    -368.0856 51321961  666.84%
417641 103611   -333.2727   267    -48.0000    -368.0856 52115151  666.84%
418995 86717   -91.4659    93     -48.0000    -368.0856 50923115  666.84%
420375 95010   -345.7725   227    -48.0000    -368.0856 51592947  666.84%
422388 97745   -208.8593   113    -48.0000    -368.0856 51806281  666.84%
*424820+95327
                           -49.0000    -368.0856          651.20%
424875 86974   -117.5452    83     -49.0000    -368.0856 50941301  651.20%
426829 88296   -141.1596   108    -49.0000    -368.0856 51174273  651.20%

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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%
9
Elapsed time = 330.56 sec. (246162.32 ticks, tree = 3912.30 MB, solutions = 30)
Nodefile size = 1679.11 MB (1484.78 MB after compression)

432487 89155      -309.7494   252     -49.0000      -368.0856 51192129 651.20%
433820 98871      -248.0751   169     -49.0000      -368.0856 51844744 651.20%
434923 89508      -95.4429    54     -49.0000      -368.0856 50996457 651.20%
436455 90671      -329.4717   245     -49.0000      -368.0856 51072363 651.20%
438281 90148      -118.6082   102     -49.0000      -368.0856 51006030 651.20%
439742 90497      -207.3705   167     -49.0000      -368.0856 51216254 651.20%
441567 90674      -173.8533   102     -49.0000      -368.0856 51016082 651.20%
443828 91216      -303.3454   206     -49.0000      -368.0856 51223635 651.20%
445236 87736      -175.7545   94     -49.0000      -368.0856 51043195 651.20%
447049 91633      -313.8024   195     -49.0000      -368.0856 51113941 651.20%
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)

```

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-----
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)
-----
12
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 2 -49.0000 -367.9753 54370598 650.97%
Elapsed time = 0.47 sec. (14.98 ticks, tree = 8107.53 MB, solutions = 30)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
449531 148553 -359.5659 442 -49.0000 -367.9753 54371140 650.97%
449538 148551 infeasible -49.0000 -367.9753 54371316 650.97%
449555 148565 -356.7244 318 -49.0000 -367.9753 54371964 650.97%
449593 148577 -332.7352 218 -49.0000 -367.9753 54373247 650.97%
449639 148602 -280.7380 198 -49.0000 -367.9753 54373435 650.97%
449702 148606 -260.2627 157 -49.0000 -367.9753 54373161 650.97%
449786 148649 -166.4203 107 -49.0000 -367.9753 54373940 650.97%
449880 148675 -94.9784 61 -49.0000 -367.9753 54374029 650.97%

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449971 148638      -203.4032   129      -49.0000    -367.9753 54375734 650.97%
450059 148698      -366.2099   443      -49.0000    -367.9753 54375106 650.97%
2
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%

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2
Elapsed time = 43.16 sec. (32219.69 ticks, tree = 8192.55 MB, solutions = 31)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
454566 149628 -364.7786 412 -50.0000 -367.6854 54432926 635.37%
454641 149685 -257.6134 147 -50.0000 -367.6854 54434532 635.37%
454765 149232 -338.9140 319 -50.0000 -367.6854 54425621 635.37%
454818 149263 -264.9478 165 -50.0000 -367.6854 54427210 635.37%
455006 148623 -232.9872 171 -50.0000 -367.6854 54453546 635.37%
455113 148698 -365.3190 406 -50.0000 -367.6854 54454977 635.37%
455205 148741 -298.9809 232 -50.0000 -367.6854 54456259 635.37%
455387 149424 -232.1075 128 -50.0000 -367.6854 54435736 635.37%
455507 148735 -264.2029 170 -50.0000 -367.6854 54427522 635.37%
455726 149833 -203.7847 140 -50.0000 -367.6854 54447876 635.37%
Elapsed time = 54.10 sec. (41946.00 ticks, tree = 8217.64 MB, solutions = 32)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
455921 149884 infeasible -50.0000 -367.6854 54452377 635.37%
455956 149909 -340.9434 221 -50.0000 -367.6854 54453965 635.37%
456118 148703 -322.7887 332 -50.0000 -367.6854 54448276 635.37%
456211 150028 -361.5807 311 -50.0000 -367.6854 54457854 635.37%
456551 150147 -90.9050 48 -50.0000 -367.6854 54458849 635.37%
456710 150218 -244.2240 146 -50.0000 -367.6854 54460397 635.37%
456937 150290 -365.6604 620 -50.0000 -367.6854 54461963 635.37%
457104 150332 -301.2754 178 -50.0000 -367.6854 54463828 635.37%
457325 149253 -317.2975 220 -50.0000 -367.6854 54475276 635.37%
457456 149351 -66.9050 55 -50.0000 -367.6854 54475951 635.37%
Elapsed time = 68.03 sec. (53360.20 ticks, tree = 8134.99 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
457550 149392 -299.9797 180 -50.0000 -367.6854 54477445 635.37%
457686 148828 -349.3764 432 -50.0000 -367.6854 54460618 635.37%
457810 148869 -286.1150 166 -50.0000 -367.6854 54462183 635.37%
458021 148956 -366.7730 1041 -50.0000 -367.6854 54465966 635.37%
458023 148958 -365.0671 968 -50.0000 -367.6854 54471615 635.37%
458024 148959 -363.9372 1032 -50.0000 -367.6854 54476003 635.37%
458026 148959 infeasible -50.0000 -367.6854 54482253 635.37%
458028 149619 -355.0212 967 -50.0000 -367.6854 54505490 635.37%
458029 149620 -354.8428 952 -50.0000 -367.6854 54509299 635.37%
458031 148960 -361.1371 1077 -50.0000 -367.6854 54490873 635.37%
11
Elapsed time = 75.01 sec. (76144.16 ticks, tree = 8099.72 MB, solutions = 33)
Nodefile size = 6060.88 MB (5290.89 MB after compression)
458035 149623 -338.0811 587 -50.0000 -367.6854 54515789 635.37%

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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)

-----
12 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%

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465201 158920      -354.1757    744      -50.0000     -367.3236 55218060 634.65%
465256 159111      -246.3611    193      -50.0000     -367.3236 55228446 634.65%
2 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      -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)

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```

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%

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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%
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%

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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.

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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)

-----
12 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%
5 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%

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497664 182720      -358.8124   331      -51.0000    -366.8762 56710686 619.37%
498118 182764      -237.3959   195      -51.0000    -366.8762 56719970 619.37%
498480 182825      -73.9050    56      -51.0000    -366.8762 56720555 619.37%
Elapsed time = 17.54 sec. (12704.97 ticks, tree = 9531.09 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)

498995 182744      -91.4849   132      -51.0000    -366.8762 56695063 619.37%
499164 182989      -359.6095   298      -51.0000    -366.8762 56716539 619.37%
499601 182253      -244.0278   167      -51.0000    -366.8762 56701358 619.37%
500209 183036      -344.9522   226      -51.0000    -366.8762 56700971 619.37%
500569 183145      cutoff      -51.0000    -366.8762 56701706 619.37%
500875 183215      -223.8724   139      -51.0000    -366.8681 56703419 619.35%
501515 183296      -345.3847   265      -51.0000    -366.8681 56704825 619.35%
502158 182831      -92.9050    50      -51.0000    -366.8681 56713383 619.35%
502527 183166      -226.7766   170      -51.0000    -366.8681 56734624 619.35%
502909 182911      -262.1243   189      -51.0000    -366.8681 56716455 619.35%
Elapsed time = 31.50 sec. (22253.24 ticks, tree = 9560.30 MB, solutions = 37)
Nodefile size = 7477.22 MB (6520.03 MB after compression)

503332 183801      -327.4005   260      -51.0000    -366.8681 56775885 619.35%
503678 183393      -63.9050    28      -51.0000    -366.8681 56750272 619.35%
503992 183427      -231.5535   138      -51.0000    -366.8681 56739737 619.35%
504587 183223      -69.9050    35      -51.0000    -366.8681 56721762 619.35%
504948 183535      -301.0740   190      -51.0000    -366.8681 56742532 619.35%
505495 184109      -189.3199   149      -51.0000    -366.8681 56735249 619.35%
505823 184172      -347.1391   255      -51.0000    -366.8681 56736378 619.35%
506089 184248      -152.5782   92      -51.0000    -366.8681 56737407 619.35%
506643 185098      -102.4718   45      -51.0000    -366.8681 56816717 619.35%
507163 183514      -94.8596    38      -51.0000    -366.8681 56762693 619.35%
Elapsed time = 46.09 sec. (31831.63 ticks, tree = 9612.19 MB, solutions = 37)
Nodefile size = 7507.91 MB (6546.68 MB after compression)

507847 183617      -150.3053   85      -51.0000    -366.8681 56764277 619.35%
508280 183802      -328.5517   206      -51.0000    -366.8681 56736660 619.35%
508940 182769      -294.7658   190      -51.0000    -366.8681 56727257 619.35%
509517 183778      -95.4761    51      -51.0000    -366.8681 56769219 619.35%
509986 183838      -290.1692   199      -51.0000    -366.8681 56771014 619.35%
510665 185497      -128.6918   82      -51.0000    -366.8681 56826754 619.35%
511065 184321      -310.4287   177      -51.0000    -366.8681 56758291 619.35%
511453 184748      -323.7543   217      -51.0000    -366.8681 56799934 619.35%
511733 185661      -352.0178   342      -51.0000    -366.8681 56831520 619.35%
512296 184878      -331.4491   218      -51.0000    -366.8681 56802445 619.35%

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2 Elapsed time = 57.78 sec. (41390.10 ticks, tree = 9769.69 MB, solutions = 37)
Nodefile size = 7582.35 MB (6611.74 MB after compression)
512740 183738 -354.3047 315 -51.0000 -366.8681 56746494 619.35%
513064 183797 -218.5924 179 -51.0000 -366.8681 56747822 619.35%
513481 184788 -81.0717 42 -51.0000 -366.8681 56759505 619.35%
513901 185908 -76.0885 72 -51.0000 -366.8681 56837494 619.35%
514340 185153 -329.4190 291 -51.0000 -366.8681 56808466 619.35%
514728 186009 -167.6558 111 -51.0000 -366.8681 56840056 619.35%
515145 186083 -313.4338 183 -51.0000 -366.8681 56841160 619.35%
515566 186176 -351.2108 233 -51.0000 -366.8681 56842573 619.35%
516099 183458 -234.0999 156 -51.0000 -366.8681 56749879 619.35%
516357 184213 -145.4731 71 -51.0000 -366.8681 56758558 619.35%
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%
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)							
<b>Nodefile size = 7507.91 MB (6546.68 MB after compression)</b>							
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)							
<b>Nodefile size = 7507.91 MB (6546.68 MB after compression)</b>							
537173	186121	-92.9050	64	-51.0000	-366.8681	56817216	619.35%
539433	186104	-360.0615	320	-51.0000	-366.8681	56829949	619.35%
541783	189363	-350.7550	227	-51.0000	-366.8681	56911498	619.35%
544525	189732	-354.4750	399	-51.0000	-366.8681	56916526	619.35%
547325	187207	-180.8447	112	-51.0000	-366.8681	56852153	619.35%
549534	187269	-359.7960	299	-51.0000	-366.8681	56841886	619.35%
552483	188561	-76.0000	37	-51.0000	-366.8681	56890908	619.35%
555018	187941	-292.0210	169	-51.0000	-366.8681	56850235	619.35%
557686	188231	-248.4755	165	-51.0000	-366.8681	56855537	619.35%
560583	190787	-328.4668	210	-51.0000	-366.8681	56924690	619.35%
Elapsed time = 165.90 sec. (130289.67 ticks, tree = 10459.45 MB, solutions = 37)							
<b>Nodefile size = 7582.35 MB (6611.74 MB after compression)</b>							
563125	189628	-59.9050	34	-51.0000	-366.8681	56911187	619.35%
565396	189136	-263.8448	164	-51.0000	-366.8681	56885160	619.35%
568071	190242	-138.8590	81	-51.0000	-366.8209	56920270	619.26%
570320	189734	-104.5327	70	-51.0000	-366.8209	56893599	619.26%

573161	191852	-256.3504	179	-51.0000	-366.8209	57017459	619.26%
575843	191145	-210.8755	128	-51.0000	-366.8209	56934904	619.26%
578475	190142	-345.4650	248	-51.0000	-366.8209	56896990	619.26%
581192	192533	-166.7373	98	-51.0000	-366.8209	57036295	619.26%
583459	192174	-248.0752	140	-51.0000	-366.8209	56949279	619.26%
585497	192912	-207.3005	124	-51.0000	-366.8209	57048453	619.26%
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%

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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%
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%
2
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%

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2 Elapsed time = 648.51 sec. (398512.68 ticks, tree = 24220.43 MB, solutions = 37)
Nodefile size = 22149.07 MB (19347.63 MB after compression)
671660 316624 -190.6028 117 -51.0000 -365.4342 61082628 616.54%
673339 316740 -255.8649 201 -51.0000 -365.4342 61117104 616.54%
675296 318619 -119.2922 64 -51.0000 -365.4342 61162844 616.54%
677401 320444 -231.1208 167 -51.0000 -365.4342 61223447 616.54%
679864 321923 -307.6958 207 -51.0000 -365.4342 61254347 616.54%
681222 323429 -355.7521 293 -51.0000 -365.4342 61293481 616.54%
682604 324985 -164.2641 90 -51.0000 -365.3694 61405616 616.41%
684015 325743 -179.6358 117 -51.0000 -365.3555 61458609 616.38%
685518 327413 -250.6560 141 -51.0000 -365.3071 61539485 616.29%
687434 328626 -146.6897 95 -51.0000 -365.3062 61584384 616.29%
Elapsed time = 708.04 sec. (436685.01 ticks, tree = 25451.98 MB, solutions = 37)
Nodefile size = 23372.09 MB (20413.94 MB after compression)
689399 329467 -99.3480 36 -51.0000 -365.2479 61635355 616.17%
691000 331344 -346.8231 238 -51.0000 -365.2050 61692904 616.09%
692237 332230 -329.2119 241 -51.0000 -365.2050 61733192 616.09%
693523 332898 -86.5479 42 -51.0000 -365.2050 61759830 616.09%
694552 333849 -187.8206 113 -51.0000 -365.1849 61826192 616.05%
696545 334946 -64.0000 28 -51.0000 -365.1849 61889587 616.05%
698225 336435 -223.7746 142 -51.0000 -365.1395 61969519 615.96%
700385 337181 -141.2558 76 -51.0000 -365.1393 61999411 615.96%
701942 339213 -228.3630 129 -51.0000 -365.1151 62061295 615.91%
703039 340138 -336.6943 518 -51.0000 -365.1074 62106040 615.90%
2 Elapsed time = 769.48 sec. (474868.46 ticks, tree = 26523.33 MB, solutions = 37)
Nodefile size = 24455.97 MB (21345.49 MB after compression)
703806 340972 -154.5474 96 -51.0000 -365.1074 62151674 615.90%
704648 342280 -338.7462 252 -51.0000 -365.1031 62231946 615.89%
705803 342510 -349.4838 328 -51.0000 -365.0948 62264654 615.87%
706909 343736 -348.7916 269 -51.0000 -365.0948 62339333 615.87%
708639 344121 -208.9617 132 -51.0000 -365.0948 62361186 615.87%
710029 345547 -179.6985 112 -51.0000 -365.0948 62447113 615.87%
711771 346626 -185.8141 108 -51.0000 -365.0912 62486059 615.87%
712627 348066 -362.4201 343 -51.0000 -365.0912 62582067 615.87%
713715 348780 -80.0606 43 -51.0000 -365.0912 62624224 615.87%
715391 349314 -306.6991 235 -51.0000 -365.0912 62666144 615.87%
Elapsed time = 824.55 sec. (513173.77 ticks, tree = 26881.08 MB, solutions = 37)
Nodefile size = 24808.87 MB (21640.42 MB after compression)
717378 350702 -353.4336 324 -51.0000 -365.0912 62715620 615.87%

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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%
<sup>2</sup> 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%
<sup>2</sup> Elapsed time = 947.27 sec. (589510.67 ticks, tree = 29838.63 MB, solutions = 37)							
Nodefile size = 27723.94 MB (24182.95 MB after compression)							
754664	378350	-313.3719	241	-51.0000	-364.9158	63637522	615.52%
755945	380009	-132.6635	77	-51.0000	-364.8896	63692159	615.47%
756996	381032	-114.4004	55	-51.0000	-364.8721	63750087	615.44%
758046	382017	-353.4691	330	-51.0000	-364.8721	63794359	615.44%
758657	382456	-354.2886	246	-51.0000	-364.8721	63843088	615.44%
759881	382519	-240.3827	153	-51.0000	-364.8710	63859500	615.43%
761113	384017	-109.7342	57	-51.0000	-364.8710	63946364	615.43%
762231	384489	-201.7776	137	-51.0000	-364.8699	63967543	615.43%
763687	385146	-167.7341	97	-51.0000	-364.8699	64005961	615.43%
764990	386464	-360.0574	326	-51.0000	-364.8699	64058084	615.43%
Elapsed time = 1005.19 sec. (627814.24 ticks, tree = 30794.27 MB, solutions = 37)							
Nodefile size = 28692.51 MB (25023.74 MB after compression)							
765714	386900	-139.3959	80	-51.0000	-364.8697	64109034	615.43%
766817	387531	-295.4339	190	-51.0000	-364.8697	64159777	615.43%
767913	388740	-70.4004	29	-51.0000	-364.8697	64211795	615.43%
768975	390150	-137.9050	71	-51.0000	-364.8697	64307062	615.43%

771045	390586	-353.6152	274	-51.0000	-364.8488	64348089	615.39%
773557	392244	-62.7203	32	-51.0000	-364.8292	64409874	615.35%
775988	394237	cutoff		-51.0000	-364.8095	64462634	615.31%
777702	396139	-166.8143	88	-51.0000	-364.8095	64503623	615.31%
779614	396520	-122.6436	68	-51.0000	-364.7910	64539613	615.28%
782146	398855	-312.5603	192	-51.0000	-364.7910	64610935	615.28%
Elapsed time = 1065.82 sec. (665982.42 ticks, tree = 32000.35 MB, solutions = 37)							
<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%

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828986 432669 -221.0570 168 -51.0000 -364.6777 65943629 615.05%
830980 435000 -274.5929 162 -51.0000 -364.6777 66001113 615.05%
833801 436907 -324.0902 213 -51.0000 -364.6475 66128348 615.00%
Elapsed time = 1245.90 sec. (780552.64 ticks, tree = 35882.93 MB, solutions = 37)
Nodefile size = 33776.48 MB (29467.99 MB after compression)

835709 439181 -133.2156 72 -51.0000 -364.6475 66178885 615.00%
837674 439908 -175.4624 114 -51.0000 -364.6475 66189714 615.00%
839601 441162 -250.9862 176 -51.0000 -364.6475 66240455 615.00%
841355 442464 -300.2932 199 -51.0000 -364.5726 66291801 614.85%
842695 444227 -317.4591 246 -51.0000 -364.5726 66361667 614.85%
844185 445795 -174.4656 98 -51.0000 -364.5726 66440393 614.85%
845686 446846 -285.6416 179 -51.0000 -364.5718 66500594 614.85%
847592 448069 -114.7342 59 -51.0000 -364.5542 66550404 614.81%
849312 448835 -257.9658 167 -51.0000 -364.5542 66582371 614.81%
851394 450013 -314.9399 211 -51.0000 -364.5542 66633782 614.81%
Elapsed time = 1307.35 sec. (818726.26 ticks, tree = 37244.89 MB, solutions = 37)
Nodefile size = 35133.82 MB (30656.34 MB after compression)

853084 452324 -312.0660 196 -51.0000 -364.5542 66693652 614.81%
854812 453846 -356.9786 261 -51.0000 -364.5542 66761242 614.81%
855968 454651 -63.4004 24 -51.0000 -364.5542 66802143 614.81%
857129 455667 -171.9293 96 -51.0000 -364.5490 66843806 614.80%
858381 456135 -163.1172 96 -51.0000 -364.5490 66892873 614.80%
860461 456922 -61.1046 29 -51.0000 -364.5490 66953083 614.80%
862972 458277 -214.0353 124 -51.0000 -364.5200 66982830 614.75%
865304 460473 -180.0223 111 -51.0000 -364.5200 67059361 614.75%
867660 461169 -321.5716 208 -51.0000 -364.4985 67072536 614.70%
870293 463316 -340.5852 217 -51.0000 -364.4819 67128946 614.67%
Elapsed time = 1368.78 sec. (856888.40 ticks, tree = 38648.48 MB, solutions = 37)
Nodefile size = 36539.17 MB (31877.98 MB after compression)

873538 467608 -217.7467 139 -51.0000 -364.4664 67233746 614.64%
876593 467125 -244.4728 135 -51.0000 -364.4574 67228464 614.62%
879178 470882 -154.9824 104 -51.0000 -364.4499 67296718 614.61%
881958 472445 -284.8297 214 -51.0000 -364.4351 67334944 614.58%
884732 474861 -279.1491 156 -51.0000 -364.4351 67377191 614.58%
887617 477416 -315.0698 194 -51.0000 -364.4211 67435378 614.55%
890379 478124 -214.2439 123 -51.0000 -364.4195 67448458 614.55%
892245 480785 -325.1725 248 -51.0000 -364.4066 67510545 614.52%
894557 482750 -324.9394 205 -51.0000 -364.4066 67569546 614.52%
896840 483406 -343.9195 287 -51.0000 -364.3964 67595487 614.50%

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5 Elapsed time = 1434.42 sec. (895055.27 ticks, tree = 41047.78 MB, solutions = 37)
Nodefile size = 38972.02 MB (34000.81 MB after compression)
898846 485804 -362.7281 405 -51.0000 -364.3964 67685395 614.50%
900772 486739 -93.3809 45 -51.0000 -364.3964 67709447 614.50%
902306 488326 -249.0641 223 -51.0000 -364.3780 67756185 614.47%
904443 489887 -182.8472 107 -51.0000 -364.3780 67817292 614.47%
906206 491028 -234.4828 133 -51.0000 -364.3780 67848657 614.47%
907466 491892 -312.0740 182 -51.0000 -364.3676 67899357 614.45%
908931 493915 -326.9604 233 -51.0000 -364.3676 67959190 614.45%
910191 494806 -275.8860 191 -51.0000 -364.3676 68017211 614.45%
911432 496455 -70.3965 32 -51.0000 -364.3676 68085484 614.45%
912334 496717 -64.4004 28 -51.0000 -364.3676 68095822 614.45%
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%

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958128 529673	-203.9004	114	-51.0000	-364.2349	69171360	614.19%
960075 531911	-80.4004	39	-51.0000	-364.2178	69250399	614.15%
961383 532901	-192.4865	122	-51.0000	-364.2178	69269827	614.15%
963351 534290	-331.6833	237	-51.0000	-364.2171	69334703	614.15%
964998 535026	-292.4749	209	-51.0000	-364.2171	69368474	614.15%
966596 537588	-233.1557	129	-51.0000	-364.2171	69455104	614.15%
968783 537908	infeasible		-51.0000	-364.1968	69462106	614.11%
970664 538749	-158.7677	91	-51.0000	-364.1944	69525096	614.11%
971877 540717	-303.3489	187	-51.0000	-364.1830	69565557	614.08%
Elapsed time = 1681.97 sec. (1047705.63 ticks, tree = 46825.36 MB, solutions = 37)						
<b>Nodefile size = 44749.88 MB (39030.34 MB after compression)</b>						
972591 541449	-360.6409	389	-51.0000	-364.1830	69614316	614.08%
973284 542393	-346.1220	219	-51.0000	-364.1810	69668081	614.08%
974504 543255	-356.6271	308	-51.0000	-364.1748	69742147	614.07%
975615 544122	-82.3339	49	-51.0000	-364.1721	69809177	614.06%
976405 544162	-359.4143	328	-51.0000	-364.1721	69815975	614.06%
978363 545748	-101.4004	57	-51.0000	-364.1668	69906213	614.05%
979846 546197	-351.0579	406	-51.0000	-364.1654	69950306	614.05%
981386 547870	-81.4004	39	-51.0000	-364.1654	69980541	614.05%
982550 549015	-333.7721	202	-51.0000	-364.1654	70056096	614.05%
983567 549656	-147.8308	79	-51.0000	-364.1654	70073713	614.05%
Elapsed time = 1742.23 sec. (1085912.50 ticks, tree = 47716.70 MB, solutions = 37)						
<b>Nodefile size = 45612.43 MB (39779.51 MB after compression)</b>						
984554 551413	cutoff		-51.0000	-364.1654	70161318	614.05%
985491 551428	-150.5823	93	-51.0000	-364.1654	70191726	614.05%
986750 552700	-282.6257	188	-51.0000	-364.1467	70255403	614.01%
988694 553598	-362.4581	443	-51.0000	-364.1387	70317096	614.00%
990679 555384	-217.3788	127	-51.0000	-364.1311	70394011	613.98%
992846 556974	-362.6461	391	-51.0000	-364.1311	70465635	613.98%
994875 556704	-249.0947	144	-51.0000	-364.1311	70449904	613.98%
996495 558587	-56.8487	28	-51.0000	-364.1193	70519524	613.96%
998699 558897	-98.4589	53	-51.0000	-364.1120	70551356	613.95%
1000118 561480	-343.5201	231	-51.0000	-364.1120	70621249	613.95%
Elapsed time = 1798.66 sec. (1124089.14 ticks, tree = 48342.35 MB, solutions = 37)						
<b>Nodefile size = 46248.91 MB (40321.99 MB after compression)</b>						
1002022 563411	-277.8063	195	-51.0000	-364.1120	70676416	613.95%
1003930 564748	-65.4004	19	-51.0000	-364.1120	70710284	613.95%
1006162 565013	-362.5691	336	-51.0000	-364.1120	70739515	613.95%
1008681 566024	-125.8004	73	-51.0000	-364.1120	70757009	613.95%

1010748	569646	-67.4004	33	-51.0000	-364.1120	70829790	613.95%
1012267	569841	-291.9516	204	-51.0000	-364.1120	70837248	613.95%
1013891	572086	-161.2518	85	-51.0000	-364.1120	70909039	613.95%
1015221	573589	-211.6472	122	-51.0000	-364.1120	70967323	613.95%
1016223	573677	-312.2773	198	-51.0000	-364.1120	70974601	613.95%
1018064	575321	-64.4004	27	-51.0000	-364.0706	71125303	613.86%
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%
5							
Elapsed time = 1988.67 sec. (1238609.25 ticks, tree = 53778.28 MB, solutions = 37)							
Nodefile size = 51644.80 MB (45060.90 MB after compression)							
1061914	607317	cutoff		-51.0000	-363.9507	72074436	613.63%
1063680	609340	-360.3288	326	-51.0000	-363.9390	72148771	613.61%
1065328	610155	-124.4046	63	-51.0000	-363.9390	72161179	613.61%
1066797	611383	-59.0000	29	-51.0000	-363.9390	72237860	613.61%
1068142	612237	-224.3689	137	-51.0000	-363.9354	72271213	613.60%
1070142	614705	-76.4004	67	-51.0000	-363.9267	72406469	613.58%
1071992	614979	-246.9402	155	-51.0000	-363.9267	72398235	613.58%

1073903	617010	-228.2843	137	-51.0000	-363.9267	72494327	613.58%
1075706	617392	-204.5836	114	-51.0000	-363.9267	72507148	613.58%
1077501	619338	-86.0025	40	-51.0000	-363.9267	72547889	613.58%
Elapsed time = 2046.66 sec. (1276770.39 ticks, tree = 54677.74 MB, solutions = 37)							
<b>Nodefile size = 52565.31 MB (45853.57 MB after compression)</b>							
1079161	620410	-209.3248	118	-51.0000	-363.9135	72608861	613.56%
1081649	622851	-300.1106	181	-51.0000	-363.8983	72686256	613.53%
1083926	623234	-323.1341	202	-51.0000	-363.8983	72691650	613.53%
1086076	625246	-193.9602	117	-51.0000	-363.8939	72732098	613.52%
1088179	627756	-283.5262	204	-51.0000	-363.8939	72790211	613.52%
1091190	628092	-287.6054	202	-51.0000	-363.8939	72814198	613.52%
1093431	629524	-254.8223	146	-51.0000	-363.8939	72854966	613.52%
1095986	632197	-346.0530	225	-51.0000	-363.8939	72931006	613.52%
1098500	634277	-179.1473	104	-51.0000	-363.8939	72978948	613.52%
1100539	636794	-187.8855	109	-51.0000	-363.8939	73044618	613.52%
Elapsed time = 2112.64 sec. (1314938.67 ticks, tree = 56546.65 MB, solutions = 37)							
<b>Nodefile size = 54466.62 MB (47506.30 MB after compression)</b>							
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)							
<b>Nodefile size = 56118.36 MB (48944.37 MB after compression)</b>							
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%

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5 Elapsed time = 2242.11 sec. (1391262.97 ticks, tree = 60633.18 MB, solutions = 37)
Nodefile size = 58549.92 MB (51084.18 MB after compression)
1152049 673941 -272.6028 196 -51.0000 -363.7500 74029925 613.24%
1154335 675960 -232.3749 144 -51.0000 -363.7346 74096293 613.21%
1156256 677959 -342.2852 228 -51.0000 -363.7346 74162994 613.21%
1158262 679301 -283.8515 185 -51.0000 -363.7346 74213670 613.21%
1160659 681152 -329.8099 233 -51.0000 -363.7346 74291318 613.21%
1163080 682052 -356.6172 229 -51.0000 -363.7346 74302383 613.21%
1164962 684898 -239.2677 149 -51.0000 -363.7346 74363108 613.21%
1166859 686253 -215.5065 147 -51.0000 -363.7035 74429048 613.14%
1169268 687434 -137.5978 79 -51.0000 -363.7026 74462687 613.14%
1171545 689622 -209.2428 119 -51.0000 -363.7026 74521715 613.14%
11 Elapsed time = 2302.32 sec. (1429431.71 ticks, tree = 61810.58 MB, solutions = 37)
Nodefile size = 59703.04 MB (52075.58 MB after compression)
1173411 692218 -356.7395 294 -51.0000 -363.7002 74586749 613.14%
1175378 692552 -168.7210 87 -51.0000 -363.6861 74594723 613.11%
1177260 694405 -353.1794 310 -51.0000 -363.6861 74666144 613.11%
1178498 695421 -323.5001 196 -51.0000 -363.6825 74706969 613.10%
1180148 696748 -157.0337 90 -51.0000 -363.6825 74757697 613.10%
1181894 698492 -174.7770 102 -51.0000 -363.6749 74851125 613.09%
1183386 700062 -74.6611 40 -51.0000 -363.6749 74931587 613.09%
1185302 699922 -80.6800 35 -51.0000 -363.6678 74926413 613.07%
1186617 701400 -271.7142 167 -51.0000 -363.6671 74988295 613.07%
1189228 702436 -317.6486 188 -51.0000 -363.6556 75016408 613.05%
? Elapsed time = 2360.98 sec. (1467594.59 ticks, tree = 62502.87 MB, solutions = 37)
Nodefile size = 60366.86 MB (52639.96 MB after compression)
1191792 705430 -255.5873 151 -51.0000 -363.6524 75108073 613.04%
1194437 706237 -124.2892 69 -51.0000 -363.6470 75131286 613.03%
1197089 707759 -307.1593 218 -51.0000 -363.6470 75162684 613.03%
1199984 710769 -130.2921 67 -51.0000 -363.6466 75226744 613.03%
1202782 713542 infeasible -51.0000 -363.6466 75289008 613.03%
1205543 714868 -250.1788 148 -51.0000 -363.6466 75306792 613.03%
1207640 716798 -324.8750 197 -51.0000 -363.6272 75347915 612.99%
1209905 717923 -274.8872 173 -51.0000 -363.6272 75381128 612.99%
1211507 720196 -128.8731 68 -51.0000 -363.6147 75451092 612.97%
1212988 721254 -185.9255 105 -51.0000 -363.6147 75476208 612.97%
Elapsed time = 2430.66 sec. (1505753.18 ticks, tree = 65025.03 MB, solutions = 37)
Nodefile size = 62942.95 MB (54909.80 MB after compression)
1214464 721679 -114.8208 59 -51.0000 -363.6147 75481562 612.97%

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1216487	723625	-345.3600	243	-51.0000	-363.6147	75547226	612.97%
1218075	723995	-323.9574	195	-51.0000	-363.6134	75552962	612.97%
1219748	725238	-302.7574	216	-51.0000	-363.6134	75612915	612.97%
1221521	726612	-361.9645	476	-51.0000	-363.5945	75637366	612.93%
1222967	728865	-342.9362	292	-51.0000	-363.5945	75726583	612.93%
1224384	730826	-247.8571	152	-51.0000	-363.5945	75797131	612.93%
1225757	731044	-330.0338	261	-51.0000	-363.5945	75791560	612.93%
1226952	732586	-258.1447	163	-51.0000	-363.5845	75882721	612.91%
1228618	732872	-321.9352	194	-51.0000	-363.5839	75927746	612.91%
Elapsed time = 2489.07 sec. (1543964.51 ticks, tree = 66176.85 MB, solutions = 37)							
Nodefile size = 64093.97 MB (55912.45 MB after compression)							
1230703	733149	-351.7396	436	-51.0000	-363.5839	75968280	612.91%
1233278	735609	-131.9364	71	-51.0000	-363.5839	76043170	612.91%
1234652	737416	-235.5213	139	-51.0000	-363.5839	76127813	612.91%
1236454	738419	-181.1871	107	-51.0000	-363.5549	76156762	612.85%
1237699	740772	-129.0000	66	-51.0000	-363.5549	76254593	612.85%
1239535	740626	-147.0000	76	-51.0000	-363.5501	76250246	612.84%
1241284	742271	-246.1793	138	-51.0000	-363.5421	76335355	612.83%
1243215	744506	-336.5570	217	-51.0000	-363.5421	76435943	612.83%
1245194	745177	-297.8112	177	-51.0000	-363.5421	76453687	612.83%
1247711	747555	-348.0724	218	-51.0000	-363.5421	76533897	612.83%
2							
Elapsed time = 2544.68 sec. (1582125.76 ticks, tree = 66528.97 MB, solutions = 37)							
Nodefile size = 64413.10 MB (56160.38 MB after compression)							
1250771	749319	-339.8761	240	-51.0000	-363.5421	76568677	612.83%
1253428	749875	-124.3338	66	-51.0000	-363.5421	76582998	612.83%
1255484	752046	-313.9867	199	-51.0000	-363.5421	76616090	612.83%
1257505	755090	-350.9171	242	-51.0000	-363.5421	76681612	612.83%
1260061	756810	-221.2307	125	-51.0000	-363.5421	76709254	612.83%
1262802	758964	-239.4641	151	-51.0000	-363.5421	76823900	612.83%
1266020	760556	-67.0000	27	-51.0000	-363.5421	76853753	612.83%
1268615	762001	-360.4381	313	-51.0000	-363.5421	76882255	612.83%
1270717	764173	-272.7824	204	-51.0000	-363.5421	76921149	612.83%
1273013	764966	-349.1395	221	-51.0000	-363.5421	76934663	612.83%
Elapsed time = 2612.51 sec. (1620287.49 ticks, tree = 68888.14 MB, solutions = 37)							
Nodefile size = 66752.03 MB (58218.78 MB after compression)							
1274910	766152	-207.9977	119	-51.0000	-363.5421	76966938	612.83%
1276895	767806	-303.6618	187	-51.0000	-363.5421	77002202	612.83%
1279341	770025	-65.0000	32	-51.0000	-363.5421	77074936	612.83%
1281908	771422	-347.6908	259	-51.0000	-363.5421	77108674	612.83%

1284101	773070	-177.3216	96	-51.0000	-363.5421	77190936	612.83%
1286070	776897	-256.3404	143	-51.0000	-363.5421	77312454	612.83%
1287980	777168	-310.7619	207	-51.0000	-363.5421	77318855	612.83%
1290484	778922	-188.5016	112	-51.0000	-363.5421	77387526	612.83%
1293069	781489	-349.1820	220	-51.0000	-363.5421	77460748	612.83%
1296398	783285	-98.9651	55	-51.0000	-363.4446	77499923	612.64%
Elapsed time = 2669.17 sec. (1658442.71 ticks, tree = 70071.06 MB, solutions = 37)							
<b>Nodefile size = 67958.53 MB (59253.49 MB after compression)</b>							
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)							
<b>Nodefile size = 71175.40 MB (62084.28 MB after compression)</b>							
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)							
<b>Nodefile size = 73464.03 MB (64075.14 MB after compression)</b>							
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%
<sup>2</sup> 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%
<sup>2</sup> 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%

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5 Elapsed time = 3060.58 sec. (1887439.56 ticks, tree = 82485.78 MB, solutions = 37)
Nodefile size = 80396.88 MB (70146.52 MB after compression)
1431870 886774 -284.1700 176 -51.0000 -363.1701 80338190 612.10%
1433655 887329 -192.0080 106 -51.0000 -363.1701 80363893 612.10%
1435683 887996 -221.9601 130 -51.0000 -363.1701 80378007 612.10%
1437806 890614 -173.4306 90 -51.0000 -363.1701 80521614 612.10%
1439772 890705 -346.6358 222 -51.0000 -363.1634 80541956 612.09%
1441413 894088 -326.9882 225 -51.0000 -363.1634 80639579 612.09%
1443300 893400 -70.0000 28 -51.0000 -363.1542 80610357 612.07%
1445035 896243 -208.7591 119 -51.0000 -363.1453 80712144 612.05%
1446281 897127 -197.6167 112 -51.0000 -363.1419 80754887 612.04%
1447762 898657 -91.8217 40 -51.0000 -363.1419 80807489 612.04%
9 Elapsed time = 3123.21 sec. (1925598.32 ticks, tree = 83544.11 MB, solutions = 37)
Nodefile size = 81452.99 MB (71050.24 MB after compression)
1449076 899736 -322.1691 203 -51.0000 -363.1419 80869707 612.04%
1450689 899823 -232.5075 136 -51.0000 -363.1318 80862276 612.02%
1452809 901413 -225.7858 139 -51.0000 -363.1314 80941867 612.02%
1454893 903274 -358.8973 388 -51.0000 -363.1282 81042552 612.02%
1457193 905392 -173.3702 95 -51.0000 -363.1282 81100657 612.02%
1459630 905749 -248.7621 160 -51.0000 -363.1229 81106133 612.01%
1462412 908405 -327.4000 317 -51.0000 -363.1193 81191230 612.00%
1465284 910018 -269.0734 163 -51.0000 -363.1193 81234773 612.00%
1467995 911192 -127.3125 68 -51.0000 -363.1193 81272725 612.00%
1470171 915051 -214.2308 131 -51.0000 -363.1193 81338792 612.00%
11 Elapsed time = 3185.87 sec. (1963768.00 ticks, tree = 85097.25 MB, solutions = 37)
Nodefile size = 82996.73 MB (72399.07 MB after compression)
1472123 915840 -61.2873 25 -51.0000 -363.0963 81359705 611.95%
1474944 917352 -150.6935 103 -51.0000 -363.0963 81406102 611.95%
1477413 918699 -206.5598 113 -51.0000 -363.0963 81437361 611.95%
1480258 921424 -164.2992 111 -51.0000 -363.0819 81482776 611.93%
1482580 921768 -268.5418 165 -51.0000 -363.0819 81488923 611.93%
1485060 924969 -143.3574 86 -51.0000 -363.0736 81569087 611.91%
1487196 925334 -228.5638 136 -51.0000 -363.0736 81574482 611.91%
1488705 927554 -163.6258 104 -51.0000 -363.0736 81634624 611.91%
1490312 928638 -309.5214 190 -51.0000 -363.0642 81673852 611.89%
1491785 929380 -358.3981 270 -51.0000 -363.0642 81684293 611.89%
Elapsed time = 3251.39 sec. (2001939.32 ticks, tree = 87079.65 MB, solutions = 37)
Nodefile size = 84914.94 MB (74090.46 MB after compression)
1493123 932100 -361.1607 431 -51.0000 -363.0642 81782395 611.89%

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1494409	933384	-226.9344	133	-51.0000	-363.0459	81815947	611.85%
1495695	934332	-340.4590	462	-51.0000	-363.0412	81876672	611.85%
1496875	935790	-83.4127	43	-51.0000	-363.0360	81930955	611.84%
1498611	936080	-340.2493	219	-51.0000	-363.0359	81938184	611.84%
1500352	938166	-344.8650	243	-51.0000	-363.0359	82058846	611.84%
1501886	939423	-214.2697	147	-51.0000	-363.0359	82133186	611.84%
1504021	940301	-358.9608	298	-51.0000	-363.0299	82162519	611.82%
1505915	940547	-111.5071	60	-51.0000	-363.0219	82169070	611.81%
1508308	942596	-290.0645	164	-51.0000	-363.0181	82259386	611.80%
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%
Elapsed time = 3438.78 sec. (2116458.32 ticks, tree = 91621.92 MB, solutions = 37)							
Nodefile size = 89472.03 MB (78071.33 MB after compression)							
1552066	975198	-257.4841	153	-51.0000	-362.9596	83217109	611.69%
1554054	978192	-362.7689	413	-51.0000	-362.9596	83329259	611.69%
1555755	978851	-143.0000	75	-51.0000	-362.9596	83355737	611.69%
1557601	980081	-111.0000	62	-51.0000	-362.9596	83402580	611.69%

1559461	980883	-65.5000	31	-51.0000	-362.9596	83416493	611.69%
1561060	981959	-95.2712	54	-51.0000	-362.9596	83457941	611.69%
1563252	984242	-362.0169	413	-51.0000	-362.9596	83525920	611.69%
1565359	985051	-357.4587	294	-51.0000	-362.9233	83550747	611.61%
1567576	986032	-149.0000	85	-51.0000	-362.9233	83574660	611.61%
1569513	987717	-279.5274	163	-51.0000	-362.9233	83634697	611.61%
<b>Elapsed time = 3504.02 sec. (2154615.60 ticks, tree = 93479.99 MB, solutions = 37)</b>							
<b>Nodefile size = 91371.26 MB (79754.57 MB after compression)</b>							
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%
<b>Elapsed time = 3565.26 sec. (2192780.39 ticks, tree = 94791.64 MB, solutions = 37)</b>							
<b>Nodefile size = 92672.34 MB (80888.26 MB after compression)</b>							
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%
<b>Elapsed time = 3635.70 sec. (2230941.04 ticks, tree = 97508.37 MB, solutions = 37)</b>							
<b>Nodefile size = 95355.95 MB (83241.89 MB after compression)</b>							
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%

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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%
9 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%
9 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%
5 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%

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5 Elapsed time = 3887.72 sec. (2383611.26 ticks, tree = 103831.56 MB, solutions = 37)
Nodefile size = 101675.30 MB (88760.66 MB after compression)
1699409 1083919 -347.0445 252 -51.0000 -362.7018 86523820 611.18%
1701903 1087178 -164.0000 86 -51.0000 -362.6903 86637076 611.16%
1705244 1087473 -111.0000 54 -51.0000 -362.6903 86641463 611.16%
1708528 1091154 -351.8627 327 -51.0000 -362.6816 86710675 611.14%
1711345 1091455 -305.5254 226 -51.0000 -362.6810 86716115 611.14%
1714058 1093531 -125.0000 68 -51.0000 -362.6810 86742733 611.14%
1716044 1093882 -270.4370 177 -51.0000 -362.6810 86747997 611.14%
1717546 1096977 -165.0000 85 -51.0000 -362.6732 86820470 611.12%
1718830 1098665 -355.7772 430 -51.0000 -362.6672 86862102 611.11%
1720069 1100901 -135.0000 80 -51.0000 -362.6656 86925829 611.11%
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%

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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%
2							
Elapsed time = 4149.17 sec. (2536284.58 ticks, tree = 111606.07 MB, solutions = 37)							
Nodefile size = 109464.13 MB (95628.95 MB after compression)							
1779471	1142822	-356.9082	300	-51.0000	-362.5778	88301076	610.94%
1781560	1145486	-345.4786	300	-51.0000	-362.5709	88354961	610.92%
1783964	1146383	-142.0000	75	-51.0000	-362.5683	88384760	610.92%
1786599	1149409	-156.9016	93	-51.0000	-362.5632	88449409	610.91%
1788528	1150674	-286.3848	175	-51.0000	-362.5575	88476984	610.90%
1790262	1152003	-152.8889	82	-51.0000	-362.5554	88530369	610.89%
1792157	1154316	-312.5151	205	-51.0000	-362.5519	88608998	610.89%
1794239	1155329	-81.4111	38	-51.0000	-362.5519	88632851	610.89%
1796795	1155687	-226.8191	121	-51.0000	-362.5490	88638195	610.88%
1798889	1157971	-242.5105	141	-51.0000	-362.5490	88695455	610.88%
2							
Elapsed time = 4216.83 sec. (2574439.80 ticks, tree = 113971.04 MB, solutions = 37)							
Nodefile size = 111820.30 MB (97713.78 MB after compression)							
1801257	1160786	-326.2609	217	-51.0000	-362.5476	88785387	610.88%
1803904	1160584	-197.5598	116	-51.0000	-362.5476	88778037	610.88%
1806916	1163684	-112.0000	59	-51.0000	-362.5476	88855097	610.88%
1809860	1164061	-164.0000	89	-51.0000	-362.5359	88860117	610.85%
1812427	1167790	-353.8110	266	-51.0000	-362.5338	88946081	610.85%
1813938	1169137	-355.4961	313	-51.0000	-362.5313	88984565	610.85%
1815156	1169515	-95.0000	50	-51.0000	-362.5280	88989276	610.84%
1816884	1172293	-109.0000	56	-51.0000	-362.5280	89054712	610.84%
1819029	1172222	-359.4854	274	-51.0000	-362.5165	89088292	610.82%
1820702	1175341	-101.0000	59	-51.0000	-362.5139	89172352	610.81%
Elapsed time = 4283.62 sec. (2612607.16 ticks, tree = 116452.58 MB, solutions = 37)							
Nodefile size = 114352.58 MB (99959.10 MB after compression)							
1821717	1175520	-316.6016	211	-51.0000	-362.5105	89178976	610.80%
1822802	1175743	-356.9446	302	-51.0000	-362.5105	89208707	610.80%
1825186	1177728	-359.8573	307	-51.0000	-362.5019	89292196	610.79%
1828466	1178524	-311.3564	177	-51.0000	-362.4955	89352642	610.78%

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1831697 1179704 -254.7012 147 -51.0000 -362.4947 89383091 610.77%
1833684 1185363 -346.5593 242 -51.0000 -362.4913 89494458 610.77%
1835958 1185747 -65.0000 35 -51.0000 -362.4905 89499237 610.77%
1838222 1187800 -349.6080 333 -51.0000 -362.4905 89556219 610.77%
1840349 1189274 -190.9810 106 -51.0000 -362.4891 89593726 610.76%
1842574 1190077 -131.0000 66 -51.0000 -362.4891 89607149 610.76%
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%

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1888119 1226301 -354.7976 297 -51.0000 -362.4143 90942207 610.62%
1889542 1227449 -292.9870 200 -51.0000 -362.4143 90980258 610.62%
1891491 1227878 -201.0640 120 -51.0000 -362.4065 90984614 610.60%
Elapsed time = 4533.80 sec. (2765317.84 ticks, tree = 122538.28 MB, solutions = 37)
Nodefile size = 120337.04 MB (105215.91 MB after compression)

1893792 1227996 -162.0000 91 -51.0000 -362.4065 91035314 610.60%
1896328 1230354 -246.3380 142 -51.0000 -362.4053 91099099 610.60%
1898667 1232386 -348.0567 224 -51.0000 -362.4034 91151758 610.59%
1900424 1234216 -202.3876 116 -51.0000 -362.3982 91202203 610.58%
1902409 1235516 -146.0000 82 -51.0000 -362.3963 91228751 610.58%
1904297 1236559 -294.4467 221 -51.0000 -362.3939 91256879 610.58%
1905946 1237273 -169.0000 91 -51.0000 -362.3926 91297562 610.57%
1908247 1238212 -359.1546 327 -51.0000 -362.3923 91327857 610.57%
1910238 1241889 -93.0000 43 -51.0000 -362.3840 91454153 610.56%
1912123 1242108 -253.7352 161 -51.0000 -362.3840 91443338 610.56%
Elapsed time = 4597.07 sec. (2803482.88 ticks, tree = 124122.99 MB, solutions = 37)
Nodefile size = 121915.48 MB (106601.21 MB after compression)

1913823 1244810 -293.5904 165 -51.0000 -362.3840 91560056 610.56%
1915261 1242831 -348.9132 224 -51.0000 -362.3840 91487721 610.56%
1917087 1245691 -357.7825 398 -51.0000 -362.3736 91596278 610.54%
1919377 1247859 -350.8520 301 -51.0000 -362.3727 91640207 610.53%
1920957 1249365 -349.1644 264 -51.0000 -362.3727 91704716 610.53%
1922448 1251919 -241.0255 135 -51.0000 -362.3727 91787046 610.53%
1924299 1251385 -139.0000 89 -51.0000 -362.3727 91745691 610.53%
1925928 1254633 -335.5796 212 -51.0000 -362.3727 91864879 610.53%
1927733 1253942 -248.7582 148 -51.0000 -362.3727 91863422 610.53%
1929800 1254954 -161.5000 98 -51.0000 -362.3727 91914276 610.53%
Elapsed time = 4665.96 sec. (2841657.11 ticks, tree = 125876.31 MB, solutions = 37)
Nodefile size = 123736.62 MB (108198.02 MB after compression)

1932915 1257567 -356.6930 308 -51.0000 -362.3727 91971230 610.53%
1935557 1257895 -235.1592 138 -51.0000 -362.3485 91975728 610.49%
1937930 1259507 -133.0000 76 -51.0000 -362.3470 92043433 610.48%
1939112 1262952 -268.7837 146 -51.0000 -362.3423 92119640 610.48%
1941120 1263559 -336.0770 228 -51.0000 -362.3380 92141033 610.47%
1943317 1266134 -78.0000 38 -51.0000 -362.3380 92201328 610.47%
1945343 1266470 -81.0000 35 -51.0000 -362.3380 92230682 610.47%
1947101 1268368 -140.3414 74 -51.0000 -362.3309 92291980 610.45%
1948917 1269242 -223.0782 125 -51.0000 -362.3309 92327936 610.45%
1950788 1269706 -57.0000 25 -51.0000 -362.3309 92331814 610.45%

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5
Elapsed time = 4731.66 sec. (2879825.80 ticks, tree = 127608.51 MB, solutions = 37)
Nodefile size = 125386.48 MB (109656.60 MB after compression)
1952593 1272828      -163.0000    86      -51.0000     -362.3309 92422770 610.45%
1955188 1273992      -348.8436   266      -51.0000     -362.3309 92476904 610.45%
1957494 1273935      -179.5526    97      -51.0000     -362.3309 92458164 610.45%
1958998 1275371      -357.5784   362      -51.0000     -362.3309 92499131 610.45%
1960528 1278994      -183.2555   100      -51.0000     -362.3309 92595513 610.45%
1962501 1279390      -143.0000    79      -51.0000     -362.3309 92614185 610.45%
1963753 1279515      -181.5109   103      -51.0000     -362.3309 92622257 610.45%
1965266 1282516      -101.0000    45      -51.0000     -362.3309 92718093 610.45%
1966607 1283982      -337.5188   281      -51.0000     -362.3309 92799904 610.45%
1968190 1282938      -315.7303   204      -51.0000     -362.3309 92761351 610.45%
9
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%
73
Elapsed time = 4857.33 sec. (2956165.23 ticks, tree = 130261.01 MB, solutions = 37)
Nodefile size = 128107.74 MB (112032.73 MB after compression)
1984197 1296305      -228.6609   123      -51.0000     -362.3074 93336345 610.41%
1985492 1296197      -177.2575   101      -51.0000     -362.3074 93393577 610.41%
1986946 1298745      -119.0000   59      -51.0000     -362.3074 93460887 610.41%
1988715 1298777      -360.0183   343      -51.0000     -362.3074 93496963 610.41%
1990344 1301907      -355.9441   253      -51.0000     -362.3074 93607408 610.41%
1992706 1302258      -120.0000   62      -51.0000     -362.2874 93612558 610.37%
1995018 1304182      -225.4859   128      -51.0000     -362.2874 93683921 610.37%
1997601 1303431      -155.8836   85      -51.0000     -362.2874 93659824 610.37%
1999960 1306782      -179.7059   100      -51.0000     -362.2874 93741768 610.37%
2001806 1307133      -277.2162   157      -51.0000     -362.2534 93746417 610.30%
Elapsed time = 4924.31 sec. (2994343.65 ticks, tree = 131623.21 MB, solutions = 37)
Nodefile size = 129402.80 MB (113165.07 MB after compression)
2003608 1310011      cutoff          -51.0000     -362.2505 93852745 610.30%

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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%

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2061571	1354213	-235.3818	137	-51.0000	-362.1701	95517218	610.14%
2062721	1354490	-178.5830	101	-51.0000	-362.1701	95521973	610.14%
2063887	1354683	-359.1123	335	-51.0000	-362.1619	95552808	610.12%
2066171	1357304	-216.6867	128	-51.0000	-362.1588	95666338	610.12%
2068842	1358733	-338.9059	219	-51.0000	-362.1540	95690539	610.11%
2071197	1359079	-151.0000	86	-51.0000	-362.1505	95694410	610.10%
			9				
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%
2							
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%

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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%
2 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%

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5 Elapsed time = 5587.16 sec. (3376070.73 ticks, tree = 149537.40 MB, solutions = 37)
Nodefile size = 147385.66 MB (128968.65 MB after compression)
2204276 1456451 -225.5052 131 -51.0000 -361.9971 98391992 609.80%
2206451 1460380 -271.7723 166 -51.0000 -361.9904 98473773 609.79%
2209077 1462514 -361.1800 374 -51.0000 -361.9904 98527678 609.79%
2212458 1462879 -197.8400 113 -51.0000 -361.9809 98522461 609.77%
2215420 1467461 -259.2272 145 -51.0000 -361.9735 98624285 609.75%
2218387 1468647 -123.6583 67 -51.0000 -361.9723 98654373 609.75%
2221372 1471853 -350.9130 263 -51.0000 -361.9667 98702789 609.74%
2225070 1470218 -121.0000 64 -51.0000 -361.9636 98673690 609.73%
2228119 1471931 -201.6745 126 -51.0000 -361.9572 98699736 609.72%
2230869 1478734 -305.8009 190 -51.0000 -361.9524 98808636 609.71%
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%
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%

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2265593 1505294 -257.5113 150 -51.0000 -361.9143 99690177 609.64%
2267732 1505621 -77.0000 31 -51.0000 -361.9143 99694602 609.64%
2269137 1508711 -65.5679 35 -51.0000 -361.9071 99827984 609.62%
2270876 1509033 -240.1320 134 -51.0000 -361.9071 99832992 609.62%
2272906 1509090 -314.8264 233 -51.0000 -361.9071 99822254 609.62%
2274629 1511601 -189.8173 101 -51.0000 -361.9002 99916173 609.61%
2275232 1511926 -147.0000 73 -51.0000 -361.9002 99933267 609.61%
2276649 1513432 infeasible -51.0000 -361.9002 99961904 609.61%
2284484 1518423 -347.9256 237 -51.0000 -361.8881 1.00e+08 609.58%
Elapsed time = 5869.03 sec. (3540255.65 ticks, tree = 158053.08 MB, solutions = 37)
Nodefile size = 155868.06 MB (136448.34 MB after compression)

2293888 1523878 -359.4920 234 -51.0000 -361.8779 1.00e+08 609.56%
2300244 1531155 -143.7059 77 -51.0000 -361.8641 1.01e+08 609.54%
2305495 1533878 -312.1851 184 -51.0000 -361.8641 1.01e+08 609.54%
2310737 1538466 -359.9087 375 -51.0000 -361.8504 1.01e+08 609.51%
2319427 1544696 -187.5489 104 -51.0000 -361.8504 1.01e+08 609.51%
2329798 1548090 -351.7499 300 -51.0000 -361.8348 1.01e+08 609.48%
2340901 1560129 -303.0342 183 -51.0000 -361.8223 1.01e+08 609.46%
2352039 1567246 -183.5988 116 -51.0000 -361.8057 1.02e+08 609.42%
2362020 1573455 infeasible -51.0000 -361.7982 1.02e+08 609.41%
2374073 1581038 -228.1897 133 -51.0000 -361.7858 1.02e+08 609.38%
Elapsed time = 6146.10 sec. (3692873.43 ticks, tree = 166163.23 MB, solutions = 37)
Nodefile size = 163955.13 MB (143560.66 MB after compression)

2383552 1588797 -311.2394 181 -51.0000 -361.7788 1.02e+08 609.37%
2391426 1596592 -100.0000 67 -51.0000 -361.7660 1.02e+08 609.35%
2399501 1604465 -353.4838 253 -51.0000 -361.7523 1.03e+08 609.32%
2406212 1609092 -187.2150 110 -51.0000 -361.7359 1.03e+08 609.29%
2414023 1613458 -99.6122 48 -51.0000 -361.7213 1.03e+08 609.26%
2423894 1621187 -346.7928 202 -51.0000 -361.7141 1.03e+08 609.24%
2432402 1623753 -181.7823 93 -51.0000 -361.7031 1.03e+08 609.22%
2441756 1636254 -339.1537 432 -51.0000 -361.6890 1.03e+08 609.19%
2448558 1638942 -357.1295 284 -51.0000 -361.6797 1.03e+08 609.18%
2454329 1646493 -207.1387 147 -51.0000 -361.6752 1.04e+08 609.17%
Elapsed time = 6408.01 sec. (3845475.54 ticks, tree = 173640.02 MB, solutions = 37)
Nodefile size = 171517.61 MB (150199.52 MB after compression)

2458581 1647298 -162.0000 89 -51.0000 -361.6752 1.04e+08 609.17%
2466444 1654276 -315.4581 198 -51.0000 -361.6752 1.04e+08 609.17%
2470355 1658826 -353.0127 356 -51.0000 -361.6752 1.04e+08 609.17%
2473616 1660657 -169.0000 93 -51.0000 -361.6752 1.04e+08 609.17%

```

2477627	1664097	-293.9190	163	-51.0000	-361.6752	1.05e+08	609.17%
2482952	1664957	-317.8915	228	-51.0000	-361.6626	1.05e+08	609.14%
2490159	1670626	-299.0124	185	-51.0000	-361.6626	1.05e+08	609.14%
2496441	1674807	-179.6537	100	-51.0000	-361.6489	1.05e+08	609.12%
2499857	1680158	-360.0926	333	-51.0000	-361.6489	1.05e+08	609.12%
2503644	1682909	-223.7228	137	-51.0000	-361.6489	1.05e+08	609.12%
2							
<b>Elapsed time = 6660.25 sec.</b> (3998105.33 ticks, tree = 177713.50 MB, solutions = 37)							
<b>Nodefile size = 175582.00 MB</b> (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							
<b>Elapsed time = 6920.25 sec.</b> (4150726.32 ticks, tree = 184835.85 MB, solutions = 37)							
<b>Nodefile size = 182651.48 MB</b> (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							
<b>Elapsed time = 7185.81 sec.</b> (4303333.35 ticks, tree = 191557.34 MB, solutions = 37)							
<b>Nodefile size = 189428.39 MB</b> (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%
2 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

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