Predicting Incident Management Service Level Agreement (SLA) Failures

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# Research Question

Summarize the original, real-data research question you identified (and obtained approval for) in Task 1. Your summary should include your justification for the research question, a description of the context in which the research question exists, and a discussion of your hypothesis.

A: RESEARCH QUESTION

The summary of the research question includes justification for the question, a description of the context, and a discussion of the hypothesis. Each of these elements align with the others and the hypothesis is plausible, given the research question.

http://www.marknagelberg.com/syncing-your-jupyter-notebook-charts-to-microsoft-word-reports/

What factors predict Incident Management SLA compliance?

## Justification for the Question

In the context of Information Technology (IT) organizations providing IT services to customers, Incident Management practices and processes serve as critical customer satisfaction enablers. Incident Management aims to minimize the duration of interruptions in normal service operations while also minimizing the impact of those interruptions (Hanna, 2011, p. 29). Service Level Agreements (SLA) describe services and establish service level targets as negotiated and agreed upon between the service provider and the customer (Hanna, 2011, p. 54). Common SLA elements identify target thresholds for the duration of incidents from initial identification (opened) to restoration of service at normal operational levels (resolved). The swift resolution of business-impacting incidents represents a primary focus for IT service support organizations. The ability to proactively identify incidents at risk of failure to meet an SLA threshold, “SLA-at-Risk”, allows for decisions and actions that reduce the duration and severity of service disruptions.

Service Desk managers, those responsible for the Incident Management process within an IT organization, will benefit from the results of this study. With customization of the data feed to a specific environment, the model will assist in identifying characteristics of incidents at risk of failure to meet an SLA (Higgins, 2016). Within the IT Service Management (ITSM) lifecycle, the results of this study will also interest Problem Management and Continual Service Improvement practitioners.

## Context

IT organizations use ITSM systems to capture information about the execution of Incident Management processes. These systems produce logs containing details about incidents, for example, the steps taken to resolve them, the individuals involved with the incidents, the elements within the IT environment impacted by the incident, and timestamps for actions taken throughout the lifecycle of an incident.

This project investigated an extract of Incident Management data from an ITSM system to determine indicators of failure to meet an SLA threshold and develop a model for predicting those incidents. Insight into SLA-at-Risk conditions notify management of IT environment components requiring attention, similar to a customer churn analysis identifying characteristics for marketing attention.

A literature scan identified related research in the field of process mining, a combination of data mining with process science (Van Der Aalst, 2018, p. 15). Amaral et al. investigated attribute selection methods to build completion time prediction models (Amaral et al., 2019). Hinkka et al. evaluated feature selection algorithms by comparing classification accuracy and response times. The study used the Gradient Boosting Machine classification method and an approximation of the mutual information score across feature selection methods on two different data sets. Sarnovsky and Surma used Random Forests and Gradient Boosting Machine classifiers to identify incident sources and predict impacts (Sarnovsky & Surma, 2018). Malley leveraged split-plot Analysis of Variance (ANOVA) techniques to assess the “extent to which IT staff use of organizational knowledge generated from data warehouse analytical measures reduces the number of IT incidents over a 30-day period”. Buhler et al. used a multinomial logistic regression model to predict impact pattern categorizations (Buhler et al., n.d., p. 13). In summary, these studies focus on questions associated with the efficiency and effectiveness of incident management practices.

## Hypothesis Discussion

As an enhancement to the above identified research, this project focuses on an alternative, original question aimed at identifying characteristics of incidents causing the greatest disruption to users and customers. The project used logistic regression analysis methods for which the following hypothesis statements apply:

H0: Data contains no significant indicators about the final SLA status of an incident (the coefficients of a logistic regression model are zero, )

H1: Data contains significant indicators about the final SLA status of an incident (the coefficients of a logistic regression model are not zero, )

# Data Collection

Report on your data collection process by describing the relevant data you collected, discussing any advantages and disadvantages of the data-gathering methodology you used, and detailing how you overcame any challenges you encountered during the process of collecting your data.

B:DATA COLLECTION

The report on the data-collection process includes a description of the data collected, a discussion of any advantages and disadvantages of the methodology used, and a discussion of how challenges in the process were overcome. Each of these elements align with each other and the methodology used was appropriate for the data collected.

This section describes the collected data, the methodology used for collection, and any associated challenges.

## Collected Data

A study investigating factors contributing to incident management SLA risk requires an extract from an ITSM system used by an IT organization for tracking incidents over a specific period. This study leveraged an existing, publicly-available data set used in the 2014 Business Processing Intelligence Challenge (BPIC) (*10th International Workshop on Business Process Intelligence 2014*, n.d.). While the challenge released four data sets, this project focused only on the Incident Records file (Van Dongen, 2014).The selected data set consists of 46,606 observations having 28 variables extracted from an ITSM system used by a bank located in the Netherlands (*Quick reference BPI Challenge 2014*, n.d.). The terms for use of the data set specify that “The user is allowed to remix, transform or build upon the data, but only for noncommercial purposes” (4TU.Centre for Research Data, 2016).

## Methodology

Data collection followed a three step approach.

### Search

The first step in data collection for an analysis project involves identifying the location and availability of relevant data sets. Search criteria identified a candidate pool of data sets with relevancy to the topic of Incident Management in an IT Service Management context. Internet-based search tools used by this project to identify publicly available subject data sets included:

* Data.Gov (<https://www.data.gov/>)
* University of California, Irvine Machine Learning Repository (<https://archive.ics.uci.edu/ml/index.php>)
* Google Scholar (<https://scholar.google.com/>)
* Google Dataset Search (<https://datasetsearch.research.google.com/>)
* Kaggle Datasets (<https://www.kaggle.com/datasets>)

### Screen

Search identified two data sets for consideration, as listed below. Both data sets contain similar information.

* 2014 Business Processing Intelligence Challenge (BPIC) Incident Records file (Van Dongen, 2014)
* UCI Machine Learning Repository Incident management process enriched event log Data Set (Amaral et al., 2019)

### Select

This project used the first data set due to the availability of supporting documents such as a detailed, accurate data dictionary and Incident Management process documentation.

## Methodology Advantages and Disadvantages

Exhibit 1. Method for Data Collection – Advantages and Disadvantages

|  |  |  |
| --- | --- | --- |
| Method | Advantages | Disadvantages |
| Internet search for candidate data sets | Broad range of results | Required filtering out cybersecurity and transportation incidents |

## Challenges

Internet searches for publicly available data sets return a large variety of results. Careful formulation and iterative refinement of search queries contributed to subsequently limiting the results to smaller, more relevant results.

# Data Extraction and Preparation

Describe your data extraction and preparation process. Provide screenshots to illustrate each step, as evidence of the work performed. Explain the tools and techniques you used for data extraction and data preparation, including how these tools and techniques were used on the data. Justify why you used these particular tools and techniques, and include any advantages or disadvantages of these choices when used with your specific data extraction and preparation methods.

C:DATA EXTRACTION AND PREPARATION

The description of the data-extraction and -preparation process includes screenshots to illustrate each step; an explanation of the tools and techniques used, including how they were used on the data; and a justification for the tools and techniques, including any advantages or disadvantages. Each of these elements aligns with the others, the methods used were appropriate for the data, and evidence of the work is provided.

This section describes the process for extracting and preparing the data for analysis followed by a discussion of the tools and techniques leveraged. See 7 Appendix of Executed Notebooks for performance illustration of each step.

## Approach

Provide screenshots to illustrate each step, as evidence of the work performed.

Data extraction and preparation involved four steps.

### Acquire

The data set required downloading from the 2014 Business Processing Intelligence Challenge (BPIC) website located at <https://www.win.tue.nl/bpi/doku.php?id=2014:challenge>. Initial exploratory data analysis (EDA) identified a relatively clean data set. Preliminary data cleaning steps included: conversion of strings representing dates to datetime data type, removal of non-incident records, as well as removal of records with a status other than closed.

### Clean

Data profiling during the previous step revealed collinearity among some variables. This step addressed some collinearity through creating aggregated variables and noted other items for later consideration. The project addressed missing values by dropping records representing fewer than 4% of the total, setting values to zero, “Not Applicable”, and “Yes/No” where appropriate (Nisbet et al., 2009, pp. 50–75).

### Engineer

The original data source lacked a binary indicator for the target variable. The project engineered the target variable, SLAFail, by setting the value to 1, according to the business rules described in Exhibit 2. Stanford University IT provides an example of a similar business rule (*Measuring Response and Resolution Times in Remedy | University IT*, n.d.).

Exhibit 2. Business Rule for SLAFail Target Variable

|  |  |
| --- | --- |
| Priority | Time Between Opened and Resolved |
| 1 Very High | Greater than 240 minutes (4 hours) |
| 2 High | Greater than 480 (8 hours) |
| 3 Medium | Greater than 1440 (1 day) |
| 4 Low | Greater than 2880 (2 days) |
| 5 Very Low | Greater than 5760 (4 days) |

The engineered target variable, FailSLA, resulted in 30% of the cases showing a failure to meet the defined SLA (closing the incident within the specified time based on Priority). The study will use proportional stratified random sampling to split the data set for training and testing purpose (Tufféry, 2011, p. 90)

### Filter and Bin

This final data extraction and preparation step addressed the high dimensionality of datetime variables and restricted the data set based on timeframe.

The datetime variables required binning (discretization) to reduce dimensionality (Tufféry, 2011, pp. 31–32). For each datetime variable (Open\_Time, Resolved\_Time, and Closed\_Time), this step created two corresponding binned variables. One for the hour of the day and the other for the day of the week.

This step reduced the data set to include only those incidents within a six-month time window (1 October 2013 through 31 March 2014). This ensures that the records cover the entire lifecycle of the incident, i.e. both open and close dates exist within the window (Buﬀett et al., 2014, p. 4). Finally, since the study proposes to predict SLA-at-Risk (SLAFail), this filtering step limited the data set used for model development to only those variables available upon creation of an incident record (Exhibit 3). Given the business case of an Incident Manager needing to identify the SLA-at-Risk incidents shortly after identification, little value would result from including data only available at later stages of an incident’s lifecycle in the model.

Exhibit 3. Final Set of Dependent Variables

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | | Description | Type |
| KM\_number | Knowledge management article containing default attributes and questions for service desk analyst use | | Categorical |
| Impact | Impact of the disruption to the customer | | Categorical |
| Urgency | Indicates incident resolution urgency | | Categorical |
| Count\_Related\_Interactions | Number of updates or changes to the incident record | | Continuous |
| Count\_Related\_Incidents | Number of similar or related incidents (child records) | | Continuous |
| Count\_Related\_Changes | Number of Change Management records associated with the incident | | Continuous |
| Open\_Time\_HourOfDay | Date and time of incident creation | | Categorical |
| Open\_Time\_DayOfWeek | Date and time of incident creation | | Categorical |
| CI\_Name\_aff | Configuration Item (CI) where the disruption is noticed | | Categorical |
| CI\_TypeSubType\_aff | Concatenation of the top-level and second-level categories for the affected CI | | Categorical |
| Service\_Component\_WBS\_aff | Service component identifier for the affected CI | | Categorical |

## Techniques and Tools

Data extraction and preparation steps leveraged techniques described in Exhibit 4.

Exhibit 4. Data Extraction and Preparation Techniques – Advantages and Disadvantages

|  |  |
| --- | --- |
| Techniques | Justification |
| Convert data types | Need to manipulate data stored as strings or numbers for recognition as type required during analysis   |  |  | | --- | --- | | Advantages | Disadvantages | | Increases data consistency and integrity | Additional time required | |
| Aggregate variables | Need to consolidate multiple categorical variables into a single variable   |  |  | | --- | --- | | Advantages | Disadvantages | | Reduces collinearity | Additional time required | |
| Engineer target variable | Need to create missing variable based on existing data   |  |  | | --- | --- | | Advantages | Disadvantages | | Establishes required data point | Introduces business rule assumptions  Additional time required | |
| Bin datetime variables | Need to consolidate multiple continuous values into discrete number of levels   |  |  | | --- | --- | | Advantages | Disadvantages | | Reduce variable dimensionality | Additional time required | |
| Filter dataset by timeframe | Need to limit data set based on subject matter expertise   |  |  | | --- | --- | | Advantages | Disadvantages | | Reduce data | Introduces business case assumptions  Additional time required | |

Tools leveraged during this stage of the study included Python, pandas, NumPy, and Pandas Profiling for data mining and statistical analysis. The mature, stable, well-documented nature of Python, the extensive availability of examples and tutorials, and availability of the selected libraries contributed to selecting Python for this project. Additionally, this project used Jupyter Notebooks to integrate discussions and narrative with the data analytics code. “For data scientists, Jupyter has emerged as a de facto standard, says Lorena Barba, a mechanical and aeronautical engineer at George Washington University in Washington DC” (Perkel, 2018). The availability of this computational notebook capability contributed to the selection of Python. Exhibit 5 describes the tools used for data extraction and preparation along with an advantage/disadvantage summary.

Exhibit 5. Data Extraction and Preparation Tools – Advantages and Disadvantages

|  |  |
| --- | --- |
| Tools | Description |
| Python (*Welcome to Python.org*, n.d.) | Programming language   |  |  | | --- | --- | | Advantages | Disadvantages | | Free, open source reduced costs | Learning curve added time | |
| pandas (*pandas—Python Data Analysis Library*, n.d.) | Data analysis and manipulation tool   |  |  | | --- | --- | | Advantages | Disadvantages | | Free, open source reduced costs | Learning curve added time | |
| NumPy (*NumPy—NumPy*, n.d.) | Scientific computing package for Python   |  |  | | --- | --- | | Advantages | Disadvantages | | Free, open source reduced costs | Learning curve added time | |
| Pandas Profiling (*Pandas\_profiling API documentation*, n.d.) | Generates data set profiles identifying data types, unique values, missing values, quantile statistics, histograms, correlations   |  |  | | --- | --- | | Advantages | Disadvantages | | Free, open source reduced costs  Ease of use reduced time | Version compatibility issues added time | |
| Jupyter Notebooks (*Project Jupyter*, n.d.) | Web-based application that integrates code, equations, visualizations, and narrative text   |  |  | | --- | --- | | Advantages | Disadvantages | | Free, open source reduced costs  Ease of use reduced time | Configuration issues added time | |

# Analysis

Report on your data analysis process by describing the analysis technique(s) you used to appropriately analyze the data. Include a justification of the tools used in your data analysis, the calculations you performed, and their resulting outputs. Explain why you selected the analysis techniques you used, and include a discussion of any advantages or disadvantages of these techniques.

D:ANALYSIS

The report on the data-analysis process includes a description of the technique(s) used and a justification of the tools used in the analysis. The report includes the calculations performed and their outputs as well as a justification of why the analysis technique(s) were selected and any advantages or disadvantages of these technique(s). The technique(s) used and the analysis were appropriate for the data.

With the goal of identifying factors that predict SLA-at-Risk incidents, the study focused on developing a logistic regression model supported by factor analysis techniques.

What factors predict Incident Management SLA compliance?

## Process Overview

Analysis developed a logistic regression model that predicts the status of SLAFail. Given the binary nature of the dependent, target variable and mixed nature of the independent variables, Tufféry recommends applying logistic regression techniques as an appropriate predictive method (Tufféry, 2011, p. 170). Analysis investigated three feature-focused aspects: variable encoding, feature selection, and feature analysis. <<say something about the optimize>>

## Calculations and Results

### Investigate Variable Encoding

The source data set contains both categorical and numeric data. This step investigated a variety of encoding techniques and tools. Exhibit 6 presents model evaluation metrics used to select an encoder for use in subsequent steps. The methodology executed the same steps while varying only the encoder used on categorical variables. This analyst chose to move forward with the Weight of Evidence (WOE) encoder given the greatest Area Under the Curve (AUC) score obtained from the Receiver Operating Characteristic (ROC) curve diagnostic obtained (Tufféry, 2011, p. 454). See the appendices for the WOE calculations performed and the results obtained.

Exhibit 6. Comparison of Model Metrics among Encoders

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Cross Validation Accuracy | F1 Score | AUC |
| MEstimate Encoder | 0.73086 | 0.65857 | 0.77668 |
| Target Encoder | 0.73394 | 0.65680 | 0.77678 |
| WOE Encoder | 0.73776 | 0.66146 | **0.78063** |
| Helmert Encoder | 0.73678 | 0.66134 | 0.76650 |

### Explore Feature Selection

The study evaluated the effectiveness of a variety of automated feature selection techniques available from SciKit-Learn (*1.13. Feature selection—Scikit-learn 0.22.1 documentation*, n.d.). Holding all other parameters equal, analysis used the feature selection methods listed in Exhibit 7 and elected to move forward with the KBest F-Classification (ANOVA F-value) method due to the highest AUC.

Exhibit 7. Comparison of Model Metrics among Feature Selection Methods

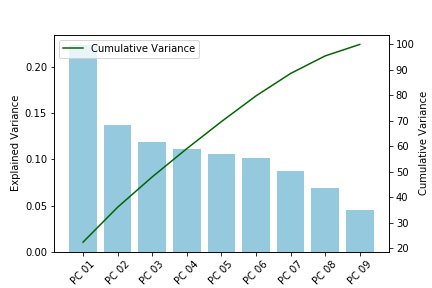
|  |  |  |  |
| --- | --- | --- | --- |
| Name | Cross Validation Accuracy | F1 Score | AUC |
| KBest F-Classification  (ANOVA F-value) | 0.737026 | 0.657922 | **0.780698** |
| KBest Mutual Information | 0.737107 | 0.654011 | 0.777989 |
| Recursive Feature Extraction | 0.735119 | 0.656594 | 0.779613 |

### Analyze Features

Considering the identification of discriminating variables as the primary purpose of the study, the project leveraged a variety of feature analysis techniques. This section describes the techniques used and presents the findings. Techniques used included: Principal Component Analysis (PCA), Factor Analysis of Mixed Data (FAMD), and Hierarchical Cluster Analysis.

#### Principal Component Analysis (PCA)

Exhibit . PCA Explained and Cumulative Variance



#### Factor Analysis of Mixed Data (FAMD)

#### Hierarchical Cluster Analysis

#### Feature Analysis Findings

### Optimize Model

## Techniques and Tools Used

### Justification of Analysis Techniques and Tools

Exhibit 9. Techniques and Tools for Analysis – Advantages and Disadvantages

|  |  |  |
| --- | --- | --- |
| Techniques and Tools | Advantages | Disadvantages |
| Weight of Evidence Coding  category\_encoders.woe.WOEEncoder |  |  |
| ANOVA F-value  sklearn.feature\_selection.SelectKBest  sklearn.feature\_selection.f\_classif |  |  |
|  |  |  |
| Logistic Regression  sklearn.linear\_model.LogisticRegression |  |  |

# Data Summary and Implications

Summarize the implications of your data analysis. Discuss the results in the context of the research question, including any limitations of your analysis. Within the context of your research question, also recommend a course of action based on your results. Then propose two directions or approaches for future study of the data set. Ensure that your recommendation and proposals for future study are directly related to your data analysis results. Your suggested proposals should be plausible; that is, they should be ideas for actual/potential future research.

E:DATA SUMMARY AND IMPLICATIONS

The summary of the implications of the data analysis includes a discussion of the data-analysis results in the context of the research question, including any limitations of the analysis. The summary also includes a recommended course of action, given the research question, as well as two directions or approaches for future study of the data. The recommendation and proposals relate to the results of the analysis and could plausibly be carried out in subsequent research.

## Discussion of Results

### Limitations

## Recommendations

### Course of Action

### Future Study

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# Appendix Describing the Source Data Set

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Type | | Description |
| Alert\_Status | | Categorical, CONSTANT value "closed" | Status for monitoring service levels |
| Category | | Categorical, four levels | Grouping of types of incidents |
| CI\_Name\_aff | | Categorical, HIGH CARDINALITY | Configuration Item (CI) where a disruption is noticed (Affected CI) |
| CI\_Name\_CBy | | Categorical, HIGH CARDINALITY | Configuration Item (CI) which caused the disruption (Caused-By CI) |
| CI\_Subtype\_aff | | Categorical, HIGH CARDINALITY | Second-level category of Affected CI |
| CI\_Subtype\_CBy | | Categorical, HIGH CARDINALITY | Second-level category of Caused-By CI |
| CI\_Type\_aff | | Categorical, 13 levels |  |
| CI\_Type\_CBy | | Categorical, 14 levels | Top-level category of Caused-By CI |
| Close\_Time | | Date Minimum: 2013-10-01 06:45:43 Maximum: 2014-03-31 22:47:32 | Date and time of incident closure |
| Closure\_Code | | Categorical, 15 levels 1.0% missing | Classification of disruption type |
| Count\_Reassignments | | Continuous, ZEROS (58.9%) | Number of times responsibility for the incident changed |
| Count\_Related\_Changes | | Continuous, MISSING (98.8%) | Number of Change Management records associated with the incident |
| Count\_Related\_Incidents | | Continuous, MISSING (97.4%) | Number of similar or related incidents (child records) |
| Count\_Related\_Interactions | | Continuous, SKEWED, MISSING (0.03%) | Number of updates or changes to the incident record |
| Handle\_Time\_Hours | | Continuous | Time required to actively resolve the incident |
| Impact | | Categorical, five levels | Impact of the disruption to the customer |
| Incident\_ID | | Categorical, UNIQUE, HIGH CARDINALITY | Unique identifier for each incident |
| KM\_number | | Categorical, HIGH CARDINALITY | Knowledge management article containing default attributes and questions for service desk analyst use |
| Open\_Time | | Date  Minimum: 2012-02-05 13:32:57 Maximum: 2014-03-31 17:24:49 | Date and time of incident creation |
| Priority | | Categorical, five levels | Priority derived from the Impact and Urgency values |
| Related\_Change | | Categorical, MISSING (98.8%), HIGH CARDINALITY | Change record identifier (if only one change is related to the incident) |
| Related\_Interaction | | Categorical, HIGH CARDINALITY | Interaction record identifier (if only one interact is related to the incident) |
| Reopen\_Time | | Date Minimum: 2013-04-10 09:15:55 Maximum: 2014-03-31 16:21:15 MISSING (95.9%), | If the incident is re-opened shortly after closure based on customer feedback, the date and time the incident was re-opened |
| Resolved\_Time | | Date Minimum: 2013-10-01 06:45:36 Maximum: 2014-03-31 22:47:29 3.8% Missing | Date and time of incident resolution |
| Service\_Component\_WBS\_aff | | Categorical, HIGH CARDINALITY | Service component identifier for the Affected CI |
| ServiceComp\_WBS\_CBy | | Categorical, HIGH CARDINALITY | Service component identifier for the Caused-By CI |
| Status | | Categorical, two levels | Status of the incident |
| Urgency | | Categorical, five levels | Indicates incident resolution urgency |

# Appendix of Executed Python Notebooks and Scripts

The following pages show the content and results generated by the Jupyter Notebooks used throughout this project.

|  |  |  |  |
| --- | --- | --- | --- |
| Report Section | Notebook Title | File Name | Page |
| 3.1.1 | 01. Exploratory Data Analysis and Preliminary Cleaning | 01. EDA\_Detail\_Incident.ipynb |  |
| 3.1.2 | 02. Cleaning the Source Data Set | 02. Cleaning\_Detail\_Incident.ipynb |  |
| 3.1.3 | 03. Creating the Target Variable (SLAFail) | 03. Create\_SLAFail.ipynb |  |
| 3.1.4 | 04. Final Data Preparation | 04. Final Data Prep.ipynb |  |
| 4.2.1 | Pick the best one as an example |  |  |
|  |  |  |  |

## Notebook: 01. Exploratory Data Analysis and Preliminary Cleaning

Output from executed notebook begins on the next page.

INSERT 01. Exploratory Data Analysis and Preliminary Cleaning

## Notebook: 02. Cleaning the Source Data Set

Output from executed notebook begins on the next page.

INSERT 02. Cleaning the Source Data Set

## Notebook: 03. Creating the Target Variable (SLAFail)

Output from executed notebook begins on the next page.

INSERT Notebook: 03. Creating the Target Variable (SLAFail)

## Notebook: 04. Final Data Preparation

Output from executed notebook begins on the next page.

INSERT 04. Final Data Preparation

## Notebook: 05.01.c Bare Bones Analysis Using a Weight of Evidence Encoder

Output from executed notebook begins on the next page.

Insert 05.01.c Bare Bones Analysis WOE Encoder.ipynb