Lessons Learned from Software Maintenance and Support Datasets

Abstract
Effort applied to the maintenance of software applications is thought to be between 60-90% [1] of the total ownership costs of the application. Yet there are significantly fewer studies focused on maintenance as compared to development, especially focused on public domain datasets. This paper presents results from a study focused on maintenance effort data from the International Software Benchmarking Standards Group - Maintenance and Support (ISBSG M&S) database.

Introduction
Estimating software sustainment costs continues to be an issue for many organizations, government agencies and their contractors. Software is not like hardware in that it does not wear out after a certain number of uses. Software is a much more malleable ‘thing’ than hardware; software developers are often asked to stretch and mold software solutions to make accommodations for limitations in the hardware or other software applications that are part of a system.

For the purpose of this study, software sustainment effort will be tracked against the following activities that occur once a software application has been first deployed. The clock on software sustainment starts when the software is first delivered into production and continues until the software application goes out of service. The categories of effort collected represent the data collected from the contributors to the ISBSG M&S database. These include:

- Maintenance Effort
  - Adaptive Maintenance
  - Corrective Maintenance
  - Perfective Maintenance
  - Preventive Maintenance

- Support Effort
  - Problem Investigation Support
  - Queries and Quick Service Support
  - User Help and Advice Support

The first section discusses in more detail what software sustainment is in the context of this study and reviews related research in this area. The second session provides an overview of the data mining process applied to this study. Following this is a brief description of the ISBSG organization and the data available for this study through this organization. The following sections describe how the data mining steps have been applied to this data as well as details of the results.

Software Sustainment
More and more systems are reliant on software for successful operations. There are many reasons for this. First and foremost is the need to keep up with ever improving technology options in both the hardware and software world. Due to budget constraints and the availability of money for research and development efforts, less new software is being developed while legacy software applications are being
corrected, enhanced, adapted and modernized in an effort to meet new threats, mission requirements, coalition configurations, etc. [1]. Software is often modified to accommodate changing requirements because it is easier to deploy than hardware. Due to this increased reliance on software and the need to make it last longer, software sustainment is a significant concern to all involved in fielding software intensive systems, consuming up to 60-90% of total costs (and effort) for many programs.

According to the Software Engineering Institute at Carnegie Mellon University (SEI/CMU) [2]:

“Software sustainment involves orchestrating the processes, practices, technical resources, information and workforce competencies for systems and software engineering, to enable system to continue mission operations and also to be able to be enhanced to meet evolving threat and capability needs.”

According to the Institute of Electrical and Electronics Engineering’s (IEEE) Standard 12207 [2]:

Software maintenance is “the process of modifying a software system after delivery to correct faults, improve performance and adapt to changing environments.”

The software sustainment activities that are part of this study are those efforts collected for the ISBSG M&S Database. These activities are:

- Adaptive Maintenance – Enhancement necessary to accommodate changes in the environment in which a software product must operate.
- Corrective Maintenance – The reactive modification of a software product performed after delivery to correct discovered problem.
- Perfective Maintenance – The modification of a software application, after delivery, to improve performance or maintainability.
- Preventative Maintenance – The modification of a software application after delivery to detect and correct latent faults in the software product before they become effective faults.
- Maintenance Management – The time that cannot be directly attributed to the maintenance of an application (e.g., Administration)
- Problem Investigation Support – This is carried out to determine if a reported incident is in fact a defect, or an error in user documentation, training, or a user error.
- Queries & Quick Service Support – One time questions that are not part of the application and can be delivered by the support team on request of the user
- User Hep & Advice Support – General support that is not related to an incident and does not involve any data extraction or manipulation.
- Support Management – The time that cannot be directly attributed to the support of an application (e.g., administration)

Many studies of software maintenance/software sustainment data towards better estimation of effort and/or cost have been done in the past. While an exhaustive search of the literature in this area has not been conducted as part of this study, it is clear that further research may be valuable to the industry. Papers such as [4],[5], and [8] present the results of regression-based analysis of data sets that don’t appear to be public. Several authors have discussed the use of Open Source Software (OSS) and change histories as the basis for maintenance effort prediction as found in [7],[10] and [11]. [6] presents a review of estimation problems in Software Maintenance. The only work similar to this study is found in [9] where
the authors used a subset of the ISBSG M&S data to predict software maintenance and support costs. This study differs from their work in that it uses the 2020 version of the ISBSG database and includes more recent data.

**Data Collection and Analysis Process**

Performing data collection correctly is not easy. And it is often problematic even when the ‘data’ is right at your fingertips because there is often drama associated with taking data, especially data collected from disparate sources, and turning it into information and (hopefully) knowledge. Regardless of the problem being solved, there are many important steps that need to be taken in order to make sure that the data collection and analysis process is structured to efficiently collect the best set of data to satisfy your data quest. According to Wikipedia [3] The ability to apply sound data mining techniques provides an important tool in the toolkit of the cost analyst or cost estimator interested in conquering large and diverse data sets.

While the data mining and analysis process is intended to be iterative as more is learned about the data, the activities that are required for a successful data mining project are detailed below:

- **Understanding the current data challenge**

  This phase represents a significant part of any such project. There needs to be a purpose and the purpose needs to be understood and accepted by project stakeholders. To put this more simply, the first step in a data mining exercise is to understand what question (or questions) need to be answered and how these answers might be used. One would not start building software without first asking what the requirements this software must fulfill. Similarly, one should not start collecting and analyzing data without asking what problem(s) the data is expected to solve.

- **Data Understanding and Preparation**

  Once the focus of the study has been identified, the next obvious step requires investigation into where and how that data might be available. Chances are good that the data required to answer a business-related question will requiring harvesting data from multiple sources within an organization or an industry. It is important that a data mining team begin to determine the data items that are likely to be required to answer the question(s) of the study and that are likely to be available for collection.

  Figuring out what data to collect and gathering it is just the start of the process. Data is often ugly, especially cost/effort data from software projects. In a perfect world, the data analyst would be able to collect spreadsheets replete with endless rows and columns rich with quantitative and qualitative information relative to the study being executed. While in a perfect world this may happen, it often doesn’t; certainly, it can be especially rare in the cost estimating community. While there are many numerical values for analysis, there is often also important non-numerical context data that has the potential to be as valuable as some of the numerical data in helping understand and analyze the data. There are also many instances where datasets are incomplete, missing data, or suspicious in nature. Datasets may require filtering to remove pieces of data that are uninteresting or irrelevant or insufficiently available in the dataset to be of value for the analysis at hand.

- **Modeling**
Models can be used for classification or prediction, depending on the question to be answered. If one is trying to determine the best audience to target advertising for a new vehicle, they may want to create a model that classifies car owners based on previous purchases. If one is trying to predict the costs of developing or sustaining software, they will want to create a predictive model to accomplish this based on outcomes of similar software projects. Having said this, the cost model builders still may want to do some classification modeling before addressing the predictive problem, because as noted earlier, there are often context details that drive stratifications in data sets.

- **Evaluation**

Clearly, once a model has been developed, it is important to make sure that the model makes sense. This evaluation involves testing the model developed against a set of data with known outcomes and ensuring that it behaves properly. It is important to review via statistical tests, the ‘goodness’ of any models developed in order to ensure credibility and to provide context, as to when it is, and is not, appropriate to use these models. It is desirable to hold back a part of the data set, when possible, to use as a test of the model developed to ensure that the model adequately responds to as many possible variations as possible. Equally important, the data mining team should always remember that sometimes the data is going to tell you something that is completely implausible; common sense should be an important tool any data mining evaluation tool set.

- **Deployment**

Once the team is happy with the model created, the next big step is to introduce it to the stakeholders who need answers to the question originally posed. This phase may involve creating a physical implementation that makes the model easy for the end user to apply, documenting this implementation and training the end users on the proper ways to use it. End users must fully understand the limitations of model use as well; a model developed using only fixed wing aircraft data may be unsuitable for predicting the costs of a rotorcraft. Deployment may also involve some evangelization on the part of the data mining team to build acceptance and confidence.

**The Data**

The International Software Benchmarking Standards Group (ISBSG) is a not for profit organization that was founded in Australia in 1997 by a group of software metrics association with the intention to help the Information Technology (IT) industry improve software processes and practices. Since their inception they have been collecting industry data from organizations all over the world. All ISBSG data is:

- Validated and rated in accordance with the ISBSG quality guidelines.
- Representative of the industry
- Independent and trusted.
- Captured from a range of organizations and industries.
- Anonymously stored in the repository [12]
In August 2020 they release Version 7 of the Maintenance and Support database containing 1177 data points, from which the data sets used for this study have been extracted. For more information about the ISBSG go to www.isbsg.org. Data from the ISBSG database can be obtained by anyone although there is a fee to purchase the data. Since it requires purchase, this author can not publish the data points that were used in this study. However, each datapoint in the ISBSG database is assigned a random identification number. Appendix B lists all the data points used for each of the two datasets studied so that any interested reader with access to the study can reference them with respect to this work.

Data Study

Understanding the questions to be answered

The intent of this study is to determine what lessons can be learned from the ISBSG M&S data and to identify ways to use these lessons to provide software maintenance and support estimation guidance to the cost community. The goal is to provide as appropriate --benchmarks aligned with industries and programming languages, cost estimating relationships (CERs)for size, effort and defects, as well as to provide other useful guidance for the cost estimators.

Although the ISBSG data set is focused on Functional Size Measures (Function Points, COSMIC Function Points, etc.), the repository also allows for the collection of KSLOC information for each of the projects reported. Another question to be answered is whether there is any indication whether KSLOC or FMs are decidedly better predictors of productivity for sustainment projects.

Preparing and understanding the data

The ISBSG M&S Database contains 1177 data points each with a potential 114 attributes or features. Appendix A contains a table that list all of the possible attribute as well as the number of data points for which that attribute is missing. Inspection of this table will help the reader understand why the datasets used in this analysis are significantly smaller than the entirety of the database.

Two datasets were collected for potential analysis – one which contained all the data points that listed IFPUG or NESMA as the Application Size Approach and one which contained a value greater than 0 for Entered KSLOC. The reason for these two choices for analysis was that IFPUG and NESMA are considered to be very comparable size measures and between them make up almost 60% of those projects that indicated an Application Size Approach in their submissions. The Entered KSLOC was selected for the KSLOC study rather than the Derived KSLOC because it was preferable that the analysis be based on real (hopefully) measured values than ones that have been derive through backfiring or some other technique.

Once the boundaries of the data study are established the next step is to prepare the data for analysis. Even though the two data sets are much smaller than the total amount of data points in the database, each is too large for data preparation and manipulation without a good set of tools. The tools used for this study include:

- RapidMiner – a data science software platform that provides an integrated environment for data preparation, machine learning, deep learning, text mining and predictive analytics. RapidMiner has an Open Source Community Version that can be downloaded and used for free (more information available at https://rapidminer.com/)
• TrueFindings® - a data analytics tool developed by PRICE® System specifically designed for data collection and analysis for cost estimators and analysts (more information available at [www.pricesystem.com](http://www.pricesystem.com))

• Microsoft® Excel

Figure 1 shows the RapidMiner process developed for the first pass of data preparation.

![RapidMiner Process for data Preparation](image)

The steps in the process are as follows:

• Retrieve the ISBSG M&S Data – since the data from the ISBSG was in the Excel format it was easily imported into RapidMiner for use in this process.

• Filter out all records for which Total Maintenance and Support Hours = 0. If Total M&S Hours is 0 that means no value was entered for either Maintenance Hours or Support Hours making these records unusable for this study.

• Filter so that all data points that do not have Application Size Approach set to IFPUG or NESMA (or Entered KSLOC for the KSLOC dataset)

• For the records that remain set the following values to 0 if they are missing. While it is not always legitimate to set missing values to 0, in this case it was deemed sensible since many submitters only fill in the total value and many projects may not collect data for some of the specific values being collected (adaptive, preventive, etc.). The same logic applies for Defect related attributes.
  - Adaptive Maintenance Hours
  - Corrective Maintenance Hours
  - Extreme Defects
  - Major Defects
  - Management Maintenance Hours
  - Management Support Hours
• Remove records where the Age of Benchmark attribute was missing. This was done because the calculation described in the Notes for this input (see Appendix A) seemed to address all possibilities of inferring this value from existing fields so there was no reasonable way to determine a good value for substituting the missing value.

• Eliminate attributes that are not needed for this study or are so scarce that including them does not make sense. Appendix C contains a list of the attributes eliminated along with the rationale.

• Filter out records missing Industry Sector. Industry Sector was well represented in the population and is likely to provide information.

• Eliminate records with Total Defects Missing

• Replace Missing Percent %P with 100 – %P is the percent of Primary Language in the application. A visual scan indicated that all records with %P missing also had no Secondary language.

• Eliminate records where the %P is equal to 0 as this makes the data record suspicious.

• Convert Data Quality Factors to Numerical values to make numerical analyses possible.

• Replace Missing Application Type and Primary Language with Numerical values to make numerical analyses possible.

• Replace Benchmark Start and End Date with Numerical Values

• Write resulting example set to a CSV file for importation into TrueFindings®.

**Benchmarks for both data sets**

Once the data is prepared, the first step is to develop benchmarks by industry, application type, and programming language for effort, size, defects, and associated productivity rates. These benchmarks are intended to provide estimators with values appropriate for sanity checks and uncertainty analysis around software maintenance estimates. Data was loaded into TrueFindings which was used to create the values for Tables 1 and 2. Figure 2 shows an example of the TrueFindings analysis capability.
Table 1 - Benchmark values for Effort, Size, and Function Points Rates for IFPUG/NESMA dataset

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sample Size</th>
<th>Min</th>
<th>Max</th>
<th>25%</th>
<th>75%</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
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<td>Age at Benchmark</td>
<td>226</td>
<td>1</td>
<td>31</td>
<td>4</td>
<td>12</td>
<td>8.85</td>
<td>8</td>
<td>3</td>
<td>6.018</td>
<td>0.68</td>
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<td>Adaptive Hours Per FP</td>
<td>30</td>
<td>0.002</td>
<td>3.894</td>
<td>0.055</td>
<td>0.423</td>
<td>0.44</td>
<td>0.197</td>
<td>0.002</td>
<td>0.768</td>
<td>1.746</td>
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<td>Adaptive Hours</td>
<td>30</td>
<td>6</td>
<td>1032</td>
<td>21.75</td>
<td>388.75</td>
<td>235</td>
<td>69</td>
<td>18</td>
<td>304.77</td>
<td>1.297</td>
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<td>Application Size</td>
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<td>24</td>
<td>55312</td>
<td>459</td>
<td>3477.8</td>
<td>2931.24</td>
<td>1261.5</td>
<td>254</td>
<td>4893.831</td>
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<td>Corrective FP Rate</td>
<td>41</td>
<td>0.002</td>
<td>4.292</td>
<td>0.038</td>
<td>0.002</td>
<td>0.002</td>
<td>0.006</td>
<td>0.004</td>
<td>0.005</td>
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<td>2</td>
<td>4224</td>
<td>24</td>
<td>132</td>
<td>120.707</td>
<td>48</td>
<td>6</td>
<td>843.871</td>
<td>2.631</td>
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<td>Extreme Defects per FP</td>
<td>183</td>
<td>1.43E-04</td>
<td>0.066</td>
<td>0.002</td>
<td>0.006</td>
<td>0.005</td>
<td>0.004</td>
<td>0.002</td>
<td>0.005</td>
<td>1.12</td>
</tr>
<tr>
<td>Extreme Defects</td>
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<td>1</td>
<td>152</td>
<td>2</td>
<td>15.5</td>
<td>12.778</td>
<td>5</td>
<td>2</td>
<td>18.525</td>
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<td>Maintenance FP Rate</td>
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<td>0.1</td>
<td>6.3</td>
<td>0.2</td>
<td>0.411</td>
<td>0.414</td>
<td>0.307</td>
<td>0.2</td>
<td>0.624</td>
<td>1.506</td>
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<td>Major Defect FP Rate</td>
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<td>0.006</td>
<td>0.012</td>
<td>0.024</td>
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<td>326.51</td>
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<td>32</td>
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<td>Management Maintenance Hours</td>
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<td>3139</td>
<td>66.25</td>
<td>283.5</td>
<td>215.326</td>
<td>149</td>
<td>52</td>
<td>291.266</td>
<td>1.353</td>
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<tr>
<td>Minor Defects Per FP</td>
<td>193</td>
<td>3.10E-04</td>
<td>0.667</td>
<td>0.016</td>
<td>0.036</td>
<td>0.037</td>
<td>0.022</td>
<td>0.05</td>
<td>0.065</td>
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<tr>
<td>Minor Defects</td>
<td>193</td>
<td>1</td>
<td>954</td>
<td>19</td>
<td>82</td>
<td>69.658</td>
<td>41</td>
<td>12</td>
<td>121.583</td>
<td>1.745</td>
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<tr>
<td>Perfective Hours per FP</td>
<td>26</td>
<td>0.006</td>
<td>0.43</td>
<td>0.03</td>
<td>0.094</td>
<td>0.078</td>
<td>0.065</td>
<td>0.086</td>
<td>0.084</td>
<td>1.076</td>
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<td>Preventive Maintenance Hours</td>
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<td>240</td>
<td>6.75</td>
<td>76.5</td>
<td>60.853</td>
<td>31</td>
<td>6</td>
<td>71.711</td>
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<tr>
<td>Preventive FP Rate</td>
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<td>0.747</td>
<td>0.034</td>
<td>0.113</td>
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<td>0.068</td>
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<td>0.16</td>
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<td>Problem Investigation FP Rate</td>
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<td>0.003</td>
<td>2.113</td>
<td>0.041</td>
<td>0.234</td>
<td>0.226</td>
<td>0.098</td>
<td>0.003</td>
<td>0.408</td>
<td>1.802</td>
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<tr>
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<td>13</td>
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<tr>
<td>Queries &amp; Quick Service Support Hours</td>
<td>33</td>
<td>1</td>
<td>3752</td>
<td>13</td>
<td>132</td>
<td>243.909</td>
<td>67</td>
<td>13</td>
<td>656.753</td>
<td>2.693</td>
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<tr>
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<td>0.003</td>
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<td>0.055</td>
<td>0.271</td>
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<td>0.037</td>
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<td>3.3</td>
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<td>0.2</td>
<td>0.337</td>
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<tr>
<td>total Defects FP Rate</td>
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<td>0.059</td>
<td>0.059</td>
<td>0.034</td>
<td>0.043</td>
<td>0.157</td>
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<td>Total Defects</td>
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<td>452</td>
<td>126</td>
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<td>Total Support Hours</td>
<td>208</td>
<td>8</td>
<td>11212</td>
<td>170.8</td>
<td>841.25</td>
<td>687.611</td>
<td>453.5</td>
<td>40</td>
<td>1021.549</td>
<td>1.486</td>
</tr>
<tr>
<td>User Help and Advise Support Hours</td>
<td>27</td>
<td>3</td>
<td>495</td>
<td>12.5</td>
<td>99.5</td>
<td>72.074</td>
<td>33</td>
<td>13</td>
<td>100.605</td>
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<tr>
<td>User Help and Advise FP Rate</td>
<td>27</td>
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<td>1.1</td>
<td>0.027</td>
<td>0.147</td>
<td>0.128</td>
<td>0.051</td>
<td>0.004</td>
<td>0.22</td>
<td>1.72</td>
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</tbody>
</table>

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Table 2 - Benchmark values for Effort, Size, and Function Points Rates for KSLOC dataset

Perusal of these tables should give the reader an idea of the layout of the data sets. The IFPUG/NESMA dataset has 226 datapoints where the KSLOC dataset contains 172 data points. Since both datasets only contain records that have Total Maintenance and Support Hours and Application Size > 0 it is obvious that these attributes are well represented. It is also apparent that values for Total Maintenance Hours, Total Support Hours, and all of the Defect related attributes are fairly well populated. What is disappointing about what both these tables reveal is that the hours for the specific maintenance and support activities (Corrective Maintenance, Adaptive Maintenance User Help & Advice Support, etc.) are poorly populated.
represented, making it clear that detailed analysis around these sub-activities is likely not the best use of analysis time.

Further scrutiny of the data using the filtering capabilities of TrueFindings did make it possible to create sets of benchmarking values for specific industries, organizations, and programming languages. The categories with adequate data to create such benchmarks are:

- **IFPUG/NESMA Dataset**
  - Primary Language
    - .Net
    - COBOL
    - Java
    - Oracle
  - Application Type
    - Business Applications
    - CRM/ERP
    - Document Management
    - Web Application
  - Industry Sector
    - Education
    - Financial
    - Government
    - Logistics
    - Utilities
  - Organization Type
    - Banking
    - Transport

- **KSLOC Dataset**
  - Primary Language
    - COBOL
    - Java
    - JCL
    - Telon
  - Industry Sector
    - Banking
    - Education
    - Government
    - Wholesale & Retail

Figures 3 and Table 2 show a sample of the stratified benchmarking values for the Industry Sector for ISBSG/NESMA for Government projects. Appendix D contains statistics and benchmarks for the other categories outlined above.
Another study was conducted to try to ascertain how effort was typically split between the various sub activities of the maintenance and support activities as well as how the various types of defects were generally spread across the total number of defects. The results led to the discovery that only a fairly small percentage of the total hour counts and total defects were broken into sub categories. It also led to an observation that not all of the Total Maintenance or Total Support attributes that did have sub-activities represented the sum of these sub activities. In other words, the sum of Total Maintenance was greater than the sum of Adapted, Corrective, Perfective, Preventative and Management even when these values were present with similar effect for the Support Hours. Tables 4 through 7 provide a distribution for maintenance and support sub activities but only in the context of those activities where they were reported. It also led to the conclusion that some of the submitters had maintenance and support effort that did not fall into any of these categories and thus reported that as part of the Total Maintenance and Total Support Hours. For this reason, as well as due to the scarcity of sub activity information, the modeling for effort was focused on the Total Maintenance Hours, Total Support Hours and Total Maintenance and Support Hours.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
<th>Count</th>
<th>Percent of Total Hours</th>
<th>Percent of Total Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptive</td>
<td>7050</td>
<td>30</td>
<td>12%</td>
<td>13%</td>
</tr>
<tr>
<td>Corrective</td>
<td>13149</td>
<td>41</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>Perfective</td>
<td>1877</td>
<td>26</td>
<td>3%</td>
<td>12%</td>
</tr>
<tr>
<td>Preventative</td>
<td>2069</td>
<td>34</td>
<td>3%</td>
<td>15%</td>
</tr>
<tr>
<td>Maintenance Management</td>
<td>37036</td>
<td>172</td>
<td>61%</td>
<td>76%</td>
</tr>
<tr>
<td>Total Maintenance</td>
<td>61181</td>
<td>216</td>
<td>96%</td>
<td></td>
</tr>
<tr>
<td>Calculated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Maintenance Entered</td>
<td>170858</td>
<td>219</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Investigation</td>
<td>3480</td>
<td>31</td>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>Queries &amp; Quick Service</td>
<td>8049</td>
<td>33</td>
<td>60%</td>
<td>15%</td>
</tr>
<tr>
<td>Support Hours</td>
<td>1946</td>
<td>27</td>
<td>14%</td>
<td>12%</td>
</tr>
<tr>
<td>Support Management</td>
<td>4</td>
<td>2</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Total Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated</td>
<td>13479</td>
<td>35</td>
<td>100%</td>
<td>15%</td>
</tr>
<tr>
<td>Total Support Entered</td>
<td>143023</td>
<td>208</td>
<td>92%</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 - IFPUG/NESMA effort by maintenance and support sub-activities.

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Total</th>
<th>Count</th>
<th>Percent of Total Defects</th>
<th>Percent of Total Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>2338.46</td>
<td>183</td>
<td>11%</td>
<td>81%</td>
</tr>
<tr>
<td>Major</td>
<td>5069.09</td>
<td>185</td>
<td>24%</td>
<td>82%</td>
</tr>
<tr>
<td>Minor</td>
<td>13444.09</td>
<td>193</td>
<td>64%</td>
<td>85%</td>
</tr>
<tr>
<td>Total Calculated</td>
<td>20851.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Entered</td>
<td>21206.05</td>
<td>219</td>
<td>97%</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 - IFPUG/NESMA Defects by sub-categories.
Modeling and evaluation

Once the data is cleansed and normalized and perused, the next step is to embark on analysis to determine what predictive value these data sets contained. This focus of this phase was primarily on regression analysis. From preliminary review of correlation matrices for the two datasets, the first observation was that there was very little correlation of interest in the KSLOC dataset. This author believes that this may be due to the fact that the primary focus of most submitters is Functional Size measures, it is quite possible that many of the KSLOC counts are either calculated through backfiring or gotten from a code counter making it likely that nuances around reuse of baseline capability which are more likely to have inform the
Functional Size measures. Deeming this an area for further study, the KSLOC part of the modeling will be tackled in a future study when there is more data or more clarity into the Entered KSLOC attribute. The KSLOC benchmarks presented earlier should still be useful if used with full knowledge of their statistical information.

While the full matrix was studied as part of the research effort, an abbreviated version of the IFPUG/NESMA Correlation matrix (eliminated attributes that displayed little to no correlation for ease of visualization) can be seen in Figure 4. It is interesting to note here that the study mentioned earlier in the paper which studied an earlier version of the ISBSG database [9] found that the most significant drivers of effort were Application Size, Defects and Team Size. The dataset analyzed in this exercise had very few samples that contains Team Size and it seemed to have very low correlation to any of the effort categories.

![Figure 4 - Abbreviated Correlation Matrix for IFPUG/NESMA Dataset](image)

RapidMiner was used to perform this analysis and was also an instrumental part of the regression analysis activity. Figure 5 shows a generalization of the Regression Process developed for this dataset.
The operators in the top two lines of this process should be familiar from the data preparation discussed earlier in this paper. The new operators that have been added to the process are described here:

- **Filter example** is used to remove values of 0 from the data set for the attributes that are slated to be independent and dependent variables in the analysis. For examples some examples do not have Support Hours because it was not reported by the submitter (possibly the organization does not track that or another department handles it) so that data point would not be a valuable addition to a study looking at drivers for Support Hours.
- **Select Attributes** selects those attributes that represent the dependent and independent variables for a particular analysis.
- **Set Role** labels the Dependent variable for a particular analysis.
- **The Cross Validation Operator** performs a Linear Regression on the entire data set and returns performance parameters.
- **The Split Data Operator** splits the data into a training set (75% of examples) and a scoring set (25% of examples).
- **The Model Created by the Linear Regression Operator** and the scoring set are sent to the **Apply Model** which determines how well the model performs on data not in the training set.

This model was applied to various combinations of Independent and Dependent Variables guided by the information provided by the Correlation Matrix. Table 8 shows an analysis of the results of these iterations. The table provides analysis based on the performance of the model against the entire data set as well as the results that are provided by the application of the model to the scoring set. The columns in the spreadsheet are:

- **Dependent Variable** – the value to be predicted.
- **Independent Variables** – the values to be considered in the prediction.
- Equation – the output of the Linear Regression Model
- R2 (Equation) – the performance of the model on the entire dataset
- Training count – the number of data points in the training set
- Scoring Count – the number of data points in the scoring set
- R2 (prediction) – the performance of the model on the scoring set
- Pred(30) – Percentage of predictions that were with +/- 30 Percent of the Actual Value
- Pred(50) – Percentage of predictions that were within +/- 40 Percent of the Actual Value

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable 1</th>
<th>Independent Variable 2</th>
<th>Independent Variable 3</th>
<th>Equation</th>
<th>R2 (equation)</th>
<th>Training Count</th>
<th>Scoring Count</th>
<th>R2 (prediction)</th>
<th>Pred(30)</th>
<th>Pred(50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Maintenance Hours</td>
<td>Application Size(app)</td>
<td>Extreme Defects (exd)</td>
<td>Major Defects (mad)</td>
<td>165.806+0.2469<em>App-12.171</em>exd-2.604*mad</td>
<td>0.949</td>
<td>134</td>
<td>45</td>
<td>0.888</td>
<td>62</td>
<td>89</td>
</tr>
<tr>
<td>Total Maintenance &amp; Support Hours</td>
<td>Application Size(app)</td>
<td>Extreme Defects (exd)</td>
<td>Major Defects (mad)</td>
<td>226.824+0.3977<em>app-0.54477</em>exd-3.6202*mad</td>
<td>0.927</td>
<td>135</td>
<td>45</td>
<td>0.483</td>
<td>38</td>
<td>56</td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Total Maintenance Hours (tothMnt)</td>
<td>202.890+0.621*tothMnt</td>
<td>0.910</td>
<td>152</td>
<td>51</td>
<td>0.959</td>
<td>47</td>
<td>76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Application Size(app)</td>
<td>Extreme Defects (exd)</td>
<td>Major Defects (mad)</td>
<td>125.929+0.3166<em>app-5.015</em>exd-5.125*mad</td>
<td>0.879</td>
<td>117</td>
<td>39</td>
<td>0.879</td>
<td>60</td>
<td>88</td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>85.746+0.193*app</td>
<td>0.855</td>
<td>164</td>
<td>55</td>
<td>0.528</td>
<td>56</td>
<td>78</td>
</tr>
<tr>
<td>Extreme Defects</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>2.83+0.0029*app</td>
<td>0.723</td>
<td>137</td>
<td>46</td>
<td>0.792</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Total Defects (td)</td>
<td></td>
<td></td>
<td>183.056+6.798*td</td>
<td>0.700</td>
<td>252</td>
<td>50</td>
<td>0.571</td>
<td>30</td>
<td>54</td>
</tr>
<tr>
<td>Total Maintenance Hours</td>
<td>Total Defects (td)</td>
<td></td>
<td></td>
<td>383.085+4.828*td</td>
<td>0.660</td>
<td>158</td>
<td>53</td>
<td>0.599</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Extreme Defects (exd)</td>
<td>Major Defects (mad)</td>
<td></td>
<td>90.571+0.798<em>exd+20.812</em>mad</td>
<td>0.659</td>
<td>131</td>
<td>43</td>
<td>0.684</td>
<td>28</td>
<td>65</td>
</tr>
<tr>
<td>Total Defects</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>314.571+31.068</td>
<td>0.632</td>
<td>164</td>
<td>55</td>
<td>0.643</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>Support Hours</td>
<td>Major Defects (mad)</td>
<td></td>
<td></td>
<td>89.802+26.7155*mad</td>
<td>0.614</td>
<td>131</td>
<td>43</td>
<td>0.674</td>
<td>27</td>
<td>60</td>
</tr>
<tr>
<td>Total Maintenance &amp; Support Hours</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>451.950+0.382*app</td>
<td>0.570</td>
<td>170</td>
<td>56</td>
<td>0.796</td>
<td>43</td>
<td>70</td>
</tr>
<tr>
<td>Total Maintenance Hours</td>
<td>Extreme Defects (exd)</td>
<td>Major Defects (mad)</td>
<td></td>
<td>160.733+52.754<em>exd-1.757</em>mad</td>
<td>0.569</td>
<td>134</td>
<td>45</td>
<td>0.388</td>
<td>42</td>
<td>51</td>
</tr>
<tr>
<td>Total Maintenance Hours</td>
<td>Extreme Defects (exd)</td>
<td></td>
<td></td>
<td>187.36+46.755*exd</td>
<td>0.537</td>
<td>135</td>
<td>45</td>
<td>0.239</td>
<td>22</td>
<td>56</td>
</tr>
<tr>
<td>Total Support Hours</td>
<td>Extreme Defects (exd)</td>
<td></td>
<td></td>
<td>263.9+3.074*exd</td>
<td>0.528</td>
<td>131</td>
<td>44</td>
<td>0.740</td>
<td>25</td>
<td>41</td>
</tr>
<tr>
<td>Maintenance Hours</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>285.422+0.173*app</td>
<td>0.510</td>
<td>164</td>
<td>55</td>
<td>0.988</td>
<td>42</td>
<td>41</td>
</tr>
<tr>
<td>Total Maintenance &amp; Support Hours</td>
<td>Total Defects (td)</td>
<td></td>
<td></td>
<td>565.88+11.33*td</td>
<td>0.510</td>
<td>164</td>
<td>55</td>
<td>0.825</td>
<td>35</td>
<td>51</td>
</tr>
<tr>
<td>Major Defects</td>
<td>Application Size(app)</td>
<td></td>
<td></td>
<td>10.00+0.0054*APP</td>
<td>0.446</td>
<td>139</td>
<td>46</td>
<td>0.393</td>
<td>19</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 8 IFPU/NESMA Regression Results

The regressions are sorted by the model that performed best across the entire dataset. It is interesting to note that the Total Support Hours are most strongly influence by Application Size but the application of Defect Information makes the relationship stronger. It is not surprising to note that Total Defects are fairly good at predicting maintenance hours even though corrective maintenance is not a significantly greater percentage of the total maintenance costs (per the percentage information shown in Table 4. This is likely to reflect the fact that all maintenance activities are more expensive if the code is lower quality. It also makes sense that Total Defects show some predictive power for Total Support Hours as lower quality software also requires additional support.

It’s also important to note that the results truly speak for themselves. Even though the dataset is fairly large, the fact that the data comes from disparate sources and although the definitions of the attributes are well spelled out in the notes, it is quite likely that different submitters interpret them differently. The most important thing to note is how different the statistics represent analysis differently. It is not unusual for the performance of the scoring test to be lower than the performance of the model on the total dataset, it’s more disturbing when the scoring results outperform the training results. Inspection of the data can explain this, but inspection is sometimes required. It is also important to note how different measures of goodness give very different interpretations of many of these models.

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Deployment

This paper and the subsequent presentation represent the first step in deployment for the results of this research. While the results are not sterling, there is information from this study that can be applied to software maintenance estimates in appropriate situations. Clearly the use needs to be tempered by an understanding what the data does and does not tell us. But certainly, additional benchmarks and CERS can become part of an estimator’s toolbox to be pulled out when they fit the need. After presentation and refinements on feedback, as well as incorporation of any additional data identified, the hope is that these benchmarks and possibly some of the CERS can find their way into guidance, rules of thumbs or findings for the cost community.

Lessons Learned

Starting with the obvious, the study did result in a better understanding of what the possibilities are for the ISBSG M&DS database. While clearly this dataset has limitations, it definitely gives a basis for the development of benchmarks and rules of thumbs that could prove useful in sanity checks for defensibility in cases where the domains and project characteristics are similar.

- Industry specific benchmarks
- Programming language specific benchmarks
- Organizational benchmarks
- Rules of thumb for allocating maintenance and support efforts throughout the lifecycle
- Rules of thumb for predicting defect types for a project

The resulting CERs, though not ideal, provide some insight into areas where the things we know about our project might help discover things unknown or only suspected:

- Potential predictors for Software Support
- Potential predictors for Software Maintenance
- Potential predictors for software program Defects

The ISBSG database, though fraught with limitations so many other cost or effort collection repositories also suffer from, still, in my opinion, is an excellent source for quality data for the software industry to use to provide benchmarks to help learn about the industry as a whole and how individual industries can improve their software processes and practice. There are however some limitations that complicated this study for me and is likely to confound others trying to maximize the value they get from this plentiful, validated source. Not just ISBSG, but any organization looking to begin or improve a data collection program may want to consider these as well.

- Several of the qualitative fields, such as Application Type and Application Description are completely freeform. While it is appropriate to provide space for submitters to add extra narrative to their submissions, having a fixed pick list for classifications important to benchmark creation and possibly CER creation would add value.
- Information about Application Set, Application Number and Application Number of would be incredibly more useful if the entries some the same project and/or the same organization were included (in an anonymous term of course) so that more analysis might be possible within types of organization. These attributes seem to be fairly well populated, but the inter-related ness of the concept is hard to work around.

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Referencing the issue where Total Maintenance Hours is not always equal to the sum of the sum of the hours of the sub-activities, maybe there is a need to allow for Other Maintenance Hours as an attribute. Understanding that it is difficult to get people to contribute data and that taking what one can get is often the best option, it would be easier to use and understand if all hours were overtly specified.

Instead of enhancement % it might be useful to characterize Application Size as Baseline and New capability.

Since there projects are being performed on existing systems, having an attribute of latent defects (those that were known to be in the product at deployment) would be useful for analysis.

Further Work
This research certainly is worthy of a second pass, preferably with some newer data added to the mix. Increased clarity on the relationships between totals and sub-categories for effort and defects would potentially enhance the analysis and improve the results. Additional data would provide an opportunity to extend the categories of benchmarks as well. As part of this study, this author began to run some excursions using some of the Machine Learning capabilities in RapidMiner such as K-Nearest Neighbor and Neural Networks with some interesting results but due to time constraints and learning curve the results are not at this time ready for prime time. Future work in this area will certainly focus on determining some innovative approaches to learning more from this data.

Cited Works


[3] https://en.wikipedia.org/wiki/Data_mining#Situation_in_the_United_States


Appendix A – ISBSG M&S Attributes (for the 487 with a Quality Rating of A or B)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISBSG ID</td>
<td>A primary key for identifying submissions to the ISBSG repository. (These Identification numbers have been 'randomised' to remove any chance of identifying a submitter).</td>
</tr>
</tbody>
</table>

**Data Quality Rating**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISBSG ID</td>
<td>A field contains an ISBSG rating code of A, B, C or D applied to the data by the ISBSG quality reviewers to denote the following:</td>
</tr>
<tr>
<td>A</td>
<td>The data submitted was assessed as being sound with nothing identified that might affect its integrity.</td>
</tr>
<tr>
<td>B</td>
<td>The submission appears fundamentally sound but there are some factors which could affect the integrity of the submitted data.</td>
</tr>
<tr>
<td>C</td>
<td>Due to significant data not being provided, it was not possible to assess the integrity of the submitted data.</td>
</tr>
<tr>
<td>D</td>
<td>The data set as a factor or a combination of factors, little credibility should be given to the submitted data.</td>
</tr>
</tbody>
</table>

**Year**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Year of data. Derived from Benchmark Period.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Benchmark</td>
<td>Age of application when benchmark was performed.</td>
</tr>
</tbody>
</table>

**Scaling Factor**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaling Factor</td>
<td>A scaling factor is derived from your period of benchmark, has been applied to effort values to enable this comparison to the ISBSG repository. This is the scaling factor required to normalise data to a one year Benchmark Period.</td>
</tr>
</tbody>
</table>

**Total Maintenance hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Maintenance hours</td>
<td>The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Support hours</td>
<td>The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

**Corrective Maintenance hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective Maintenance hours</td>
<td>The reactive modification of a software product performed after delivery to correct discovered problems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective Maintenance hours</td>
<td>Corrective Maintenance: The reactive modification of a software product performed after delivery to correct discovered problems.</td>
</tr>
</tbody>
</table>

**Adaptive Maintenance hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Maintenance hours</td>
<td>Preventive maintenance efforts that cannot be directly attributed to the maintenance of an application (e.g. administration).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Maintenance hours</td>
<td>Adaptive Maintenance: Enhancements necessary to accommodate changes in the environment in which a software product must operate.</td>
</tr>
</tbody>
</table>

**Management Maintenance hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Maintenance hours</td>
<td>The time that cannot be directly attributed to the maintenance of an application (e.g. administration).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Maintenance hours</td>
<td>Management Maintenance: Management support effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

**Total Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Support hours</td>
<td>Total support work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Support hours</td>
<td>Total Support hours: The time that cannot be directly attributed to the support of an application (e.g. Administration).</td>
</tr>
</tbody>
</table>

**Problem Investigation Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Investigation Support hours</td>
<td>The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Investigation Support hours</td>
<td>Problem Investigation: The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

**Queries & Quick Service Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queries &amp; Quick Service Support hours</td>
<td>The time that cannot be directly attributed to the support of an application (e.g. Administration).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queries &amp; Quick Service Support hours</td>
<td>Queries &amp; Quick Service: One-time questions that are not part of the application and can be delivered by the support team on request of the user.</td>
</tr>
</tbody>
</table>

**User Help & Advice Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Help &amp; Advice Support hours</td>
<td>The time that cannot be directly attributed to the support of an application (e.g. Administration).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Help &amp; Advice Support hours</td>
<td>User Help &amp; Advice: General support that is not related to an incident and does not involve any data extraction or manipulation.</td>
</tr>
</tbody>
</table>

**Management Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Support hours</td>
<td>The time that cannot be directly attributed to the support of an application (e.g. Administration).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Support hours</td>
<td>Management Support: The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
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</tbody>
</table>

**Total Maintenance & Support hours**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Maintenance &amp; Support hours</td>
<td>The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Maintenance &amp; Support hours</td>
<td>Total Maintenance &amp; Support: The total work effort in hours for a 12 month period, converted to hours where recorded otherwise.</td>
</tr>
</tbody>
</table>

**Maintenance KSLOC rate**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance KSLOC rate</td>
<td>Application maintenance rate calculated as Total Effort (in hours) normalised to one year, divided by Application Size (in KSLOC).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance KSLOC rate</td>
<td>Maintenance KSLOC rate is expressed as: (Total Effort [in hours] / Application Size [in KSLOC])</td>
</tr>
</tbody>
</table>

**Maintenance FP rate**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance FP rate</td>
<td>Application maintenance rate calculated as Total Effort (in hours) normalised to one year, divided by Application Size (in FP).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance FP rate</td>
<td>Maintenance FP rate is expressed as: (Total Effort [in hours] / Application Size [in FP])</td>
</tr>
</tbody>
</table>

**Support FP rate**

<table>
<thead>
<tr>
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<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>Support FP rate</td>
<td>Application support rate calculated as Support Effort (in hours) normalised to one year, divided by Application Size (in FP).</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support FP rate</td>
<td>Support FP rate is expressed as: (Support Effort [in hours] / Application Size [in FP])</td>
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</table>

**Functional rate**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>Functional rate</td>
<td>Application functional rate calculated as Total Effort (in hours) normalised to one year, divided by Application Size (in KSLOC).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional rate</td>
<td>Functional rate is expressed as: (Total Effort [in hours] / Application Size [in KSLOC])</td>
</tr>
</tbody>
</table>

**Maintenance KSOLOC rate**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance KSOLOC rate</td>
<td>Application maintenance rate calculated as Total Effort (in hours) normalised to one year, divided by Application Size (in KSOLOC).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance KSOLOC rate</td>
<td>Maintenance KSOLOC rate is expressed as: (Total Effort [in hours] / Application Size [in KSOLOC])</td>
</tr>
</tbody>
</table>

**Support KSOLOC rate**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support KSOLOC rate</td>
<td>Application support rate calculated as Support Effort (in hours) normalised to one year, divided by Application Size (in KSOLOC).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support KSOLOC rate</td>
<td>Support KSOLOC rate is expressed as: (Support Effort [in hours] / Application Size [in KSOLOC])</td>
</tr>
</tbody>
</table>

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KSLOC rate
- KSLOC rate calculated as Total Application Effort (in hours) normalised to one year period, divided by Application Size (in KSLOC).
- KSLOC rate is expressed as:

Enhancement %
- Enhancement %: Percentage of maintenance time spent on small enhancements
- Enhancement % is calculated only where the breakdown of maintenance effort is available.

Team Size
- Team Size: Application team size of the maintenance and support team

User Organisation type
- User Organisation type: The industry(s) in which the software's end users work

Industry sector
- Industry sector: Grouping key for submissions by industry type of the organisation running the software

Benchmark start date
- Benchmark start date: Start date of benchmark period

Benchmark end date
- Benchmark end date: End date of benchmark period

FTE hours
- FTE hours: Number of worked hours per Full Time Equivalent (FTE), for the Maintenance and Support Staff Year

Staff size
- Staff size: Complete Software Maintenance and Support Staff size

Portfolio
- Portfolio: Total Number of applications in the Portfolio

Applications - small
- Number of small applications in the Portfolio

Applications - medium
- Number of medium applications in the Portfolio

Applications - large
- Number of large applications in the Portfolio

Portfolio size
- Portfolio size: The total combined size of all applications in the organisation

Portfolio size approach
- Portfolio size approach: The using method used to size applications in the organisation

Total Maintenance FTE
- This is the sum of:
  - Perfection Maintenance
  - Preservation Maintenance
  - Corrective Maintenance
  - Adaptive Maintenance

Total Support FTE
- This is the sum of:
  - Problem Investigation, Help and Advice
  - Queries and Quick services

Total M&S FTE
- This is the sum of:
  - Total Software Maintenance and Support Effort for the organisation

Application Description
- Application Description: Description of the software application

Conventional wisdom indicates that it is likely that more complex application types will require greater maintenance effort. This identifies the type of application being addressed by the M&S activity. This is one of the 'normative' measures used to draw comparisons. The size should be expressed in one of the full or interim status sizing methods accepted by ISBSG (see Portfolio size approach).
<table>
<thead>
<tr>
<th><strong>Application size</strong></th>
<th>The functional size of the application which is a major factor in maintenance effort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application size approach</strong></td>
<td>The sizing method used to size the application</td>
</tr>
<tr>
<td><strong>Application size</strong></td>
<td>The size should be expressed in one of the full or interim status sizing methods accepted by ISBSG (see Application size approach)</td>
</tr>
<tr>
<td><strong>Application size approach</strong></td>
<td>The sizing method used to size the application</td>
</tr>
<tr>
<td><strong>Application size</strong></td>
<td>This should be one of the full or interim status sizing methods accepted by ISBSG:</td>
</tr>
<tr>
<td><strong>Other size approach</strong></td>
<td>The sizing method used to size the application</td>
</tr>
<tr>
<td><strong>Other size</strong></td>
<td>The functional size of the application where the method used is not listed by ISBSG</td>
</tr>
<tr>
<td><strong>Other size approach</strong></td>
<td>This should be one of the full or interim status sizing methods accepted by ISBSG:</td>
</tr>
<tr>
<td><strong>Total Support Effort</strong></td>
<td>It is essential that all effort values are expressed in the same unit and that this unit is indicated</td>
</tr>
<tr>
<td><strong>Total M&amp;S Effort</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Benchmark Period (Days)</strong></td>
<td>It is essential that all effort values are expressed in the same unit and that this unit is indicated</td>
</tr>
<tr>
<td><strong>Launch date</strong></td>
<td>The application launch date which is the date or year of the last major release or re-launch</td>
</tr>
<tr>
<td><strong>Not important process</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Important process</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Critical process</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Business target</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Critical target</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Unit of Maint</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Unit of Support</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Total Support Effort</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
<tr>
<td><strong>Total M&amp;S Effort</strong></td>
<td>The number of days during which the maintenance and support effort was recorded.</td>
</tr>
</tbody>
</table>

**Staff Years** = Hours divided by 1440

**Staff Months** = Hours divided by 120

**Staff Day** = Hours divided by 6

Where expressed in days or months (or where FTE and FTE hours/year is not given) a conversion is used:

The effort should be expressed as FTE staff years (with FTE hours/year given) or hours

The unit of the total effort

The unit of Support

The number of days during which the maintenance and support effort was recorded.

The number of days during which the maintenance and support effort was recorded.

The functional size of the application which is a major factor in maintenance effort

The number of days during which the maintenance and support effort was recorded.

The functional size of the application which is a major factor in maintenance effort

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**

**Benchmark Period (Days)**

**Launch date**

**Not important process**

**Important process**

**Critical process**

**Business target**

**Critical target**

**Unit of Maint**

**Unit of Support**

**Total Support Effort**

**Total M&S Effort**
<table>
<thead>
<tr>
<th>Product versions</th>
<th>Number of versions of the product</th>
<th>The higher the number of versions of the product, the higher is the expectation of maintenance/support effort, as this would influence testing effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating systems</td>
<td>Number of Operating systems supported</td>
<td>The higher the number of Operating systems simultaneously supported by the product, the higher is the expectation of maintenance/support effort, as this would influence testing effort</td>
</tr>
<tr>
<td>Data bases</td>
<td>Number of data bases supported</td>
<td>The higher the number of Databases supported by the product, the higher is the expectation of maintenance/support effort, as this would influence testing effort</td>
</tr>
<tr>
<td>Third Party Products</td>
<td>The contribution of third party products such as packages to the application being supported. It is expected that parameterised packages may be easier to adapt than bespoke applications.</td>
<td>If third party products are used information may be supplied on:</td>
</tr>
<tr>
<td>Product name</td>
<td>If third party products are used this is the name of the product</td>
<td></td>
</tr>
<tr>
<td>Language used</td>
<td>The language used in third party products</td>
<td></td>
</tr>
<tr>
<td>Third Party Package</td>
<td>If third party products are used this indicates whether this is:</td>
<td></td>
</tr>
<tr>
<td>Code maintained</td>
<td>If third party products are used this indicates if code is:</td>
<td></td>
</tr>
<tr>
<td>Parameter maintained</td>
<td>If third party products are used this indicates if parameters are:</td>
<td></td>
</tr>
<tr>
<td>Third Party Ownership</td>
<td>This indicates the extent of ownership of third party product. Partial ownership could be a possibility where for a very critical application, high severity defect correction is not outsourced.</td>
<td></td>
</tr>
<tr>
<td>Hardware</td>
<td>The hardware used in the primary platform</td>
<td></td>
</tr>
<tr>
<td>HW number</td>
<td>This is the number of hardware units at this level of the platform</td>
<td></td>
</tr>
<tr>
<td>Operating System</td>
<td>The operating system on which the larger proportion of the application function is hosted</td>
<td></td>
</tr>
<tr>
<td>DBMS</td>
<td>DBMS is the database management system used</td>
<td></td>
</tr>
<tr>
<td>Platform Role</td>
<td>Platform role is used to describe, as far as possible, the role the platform</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Language</th>
<th>KSLOC</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>84</td>
<td>382</td>
</tr>
<tr>
<td>Secondary</td>
<td>94</td>
<td>323</td>
</tr>
<tr>
<td>Third</td>
<td>406</td>
<td>187</td>
</tr>
<tr>
<td>4th</td>
<td>657</td>
<td>455</td>
</tr>
<tr>
<td>5th</td>
<td>404</td>
<td>454</td>
</tr>
<tr>
<td>6th</td>
<td>406</td>
<td>406</td>
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<tr>
<td>7th</td>
<td>484</td>
<td>484</td>
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<tr>
<td>8th</td>
<td>485</td>
<td>485</td>
</tr>
<tr>
<td>9th</td>
<td>485</td>
<td>485</td>
</tr>
<tr>
<td>10th</td>
<td>485</td>
<td>485</td>
</tr>
</tbody>
</table>

KSLOC (P): The primary programming language that is used to program the bulk of the application.

KSLOC (S): The secondary programming language that is used to program the application.

KSLOC (T): The third programming language that is used to program the application.

KSLOC (4): The fourth programming language that is used to program the application.

KSLOC (5): The fifth programming language that is used to program the application.

KSLOC (6): The sixth programming language that is used to program the application.

KSLOC (7): The seventh programming language that is used to program the application.

KSLOC (8): The eighth programming language that is used to program the application.

KSLOC (9): The ninth programming language that is used to program the application.

KSLOC (10): The tenth programming language that is used to program the application.

% (P): The primary programming language expressed as a percentage figure.

% (S): The secondary programming language expressed as a percentage figure.

% (T): The third programming language expressed as a percentage figure.

% (4): The fourth programming language expressed as a percentage figure.

% (5): The fifth programming language expressed as a percentage figure.

% (6): The sixth programming language expressed as a percentage figure.

% (7): The seventh programming language expressed as a percentage figure.

% (8): The eighth programming language expressed as a percentage figure.

% (9): The ninth programming language expressed as a percentage figure.

% (10): The tenth programming language expressed as a percentage figure.

(Note: this is thousand lines of code, not units of lines of code.)

Amount of code expressed as a percentage figure of the total lines of code.

Amount of code in number of KSLOC of the language that is used to program the application.
### Appendix B – ISBSG Data Points used in IFPUG/NESMA and KSLOC Studies

<table>
<thead>
<tr>
<th>ISBSG</th>
<th>IFPUG/NESMA</th>
<th>KSLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>10006</td>
<td>12446</td>
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</tr>
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<tr>
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Appendix D – Benchmarks for Industry Sector, Application Types, Primary Languages

D.1 – IFPUG/NESMA by Industry Sector

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### Education

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### IFPUG/NESMA PRIMARY LANGUAGE DATA POINTS

- **.Net** 40
- **COBOL** 51
- **Java** 48
- **Oracle** 43
- **Other** 44
- **Total** 226

D.3 – IFPUG/NESMA Benchmarks by Primary Language

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# D.4 KSLOC Benchmarks by Primary Language

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