# Do Different Functionality Types Affect the Relationship between Software Functional Size and Effort?

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**Abstract.** Effort estimation is a significant practical problem in software engineering, and various cost drivers, including software size, which might have an impact on it have been explored. In many of these studies, total software size (measured in either lines of code or functional size units) is the primary input. However, the relationship between effort and the components of functional size has not yet been fully analyzed. This study explores whether effort estimation models based on the functional size components, that is, Base Functional Component types, rather than those based on a single total value, would improve estimation models. For this empirical study, the project data in the International Software Benchmarking Standards Group (ISBSG) Release 10 dataset, which were sized by the COSMIC FFP method, are used.

**Keywords:** Functional Size Measurement, Effort Estimation, COSMIC-FFP, Base Functional Component, International Software Benchmarking Standards Group (ISBSG)

## 1 Introduction

The planning, monitoring and control of software development projects require that effort and costs be adequately estimated. However, some forty years after the term “software engineering” was coined [24], effort estimation still remains a challenge for practitioners and researchers alike.

There is a large body of literature on software effort estimation models and techniques in which a discussion on the relationship between software size and effort as a primary predictor has been included, such as [2][5][6] [11][12][13][14]. Other factors related to non-functional characteristics of software projects – also referred to as cost drivers in the COCOMO estimation models and their variants [5][6] – are also included in many estimation models.

In [18], Leung and Fan discuss both the strengths and weaknesses of effort estimation models. They evaluate the performance of existing models, which they deem unsatisfactory, as well as that of newer approaches to software estimation. Similarly, in a number of studies, such as [2][15][16][17], related work on effort and cost estimation models is assessed and compared. They conclude that the models, which are being used by different groups and in different domains, have still not gained universal acceptance.

In particular, the nature of the relationship between functional size and effort has been explored in many studies. But, up to now, no model is considered to perform well enough to fully meet market needs and expectations. The common approach of these studies is that, the functional size of a software system is expressed as a single value obtained by a specific FSM method. This single value is derived from a measurement function in all ISO-certified FSM methods, and it is the result of adding together the functional sizes of different Base Functional Component (BFC)[1] Types to obtain a total functional size.

In the study presented here, effort estimation models based on the functional size of BFC Types, rather than the total functional size, are explored to investigate whether or not they improve estimation reliability. Our hypothesis is that the effort required to develop the unit size of each of the BFC Types, which provide different user functionalities, is different.

For the statistical analyses, the project data, which were measured by the Common Software Measurement International Consortium's Full Function Points (COSMIC-FFP) [41] and contained in the ISBSG 2007 database, Release 10, are used [10].

The paper is organized as follows: Section 2 presents some background on functional size measurement and related work on its relationship to project effort. Section 3 presents the data preparation. Section 4 presents the data analysis and section 5, a summary.

## 2 Background

### 2.1. Functional Size Measurement – A Brief Outline

Function Point Analysis (FPA) was designed initially in 1979 [1] by Allan Albrecht, an IBM researcher. This method was aimed at overcoming some of the shortcomings of measures based on lines of code for estimation purposes and productivity analysis, such as their availability only fairly late in the development process and their technology dependence. The FPA method was based on the idea of determining size based on the functional requirements and from the end user's viewpoint, taking into account only those elements in the application layer that are logically 'visible' to the user and not the technology used.

FPA was designed in an MIS environment and has become a *de facto* standard in the MIS community. However, it generated a large number of variants for both MIS and non-MIS environments (such as real-time, Web, Object Oriented, and data warehouse systems)[2]. In the '90s, work was initiated at the ISO level to lay the foundations for regulating *de jure* standards in Functional Size Measurement (FSM),

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[1] BFC Type: A defined category of BFCs. A BFC is an elementary unit of an FUR defined by and used by an FSM method for measurement purposes [27].

[2] Please refer to [38] and [8] for a detailed list and a history of FPA-like methods.

and the 14143 family was developed [27][3] [29]-[33] with four instantiations matching with those requirements: COSMIC-FFP [41][34], the International Function Point Users Group (IFPUG) FPA [39][35], MarkII FPA [40][36] and The Netherlands Software Metrics Association (NESMA) FSM [37] methods. The evolution of FSM methods is shown in Figure 1.

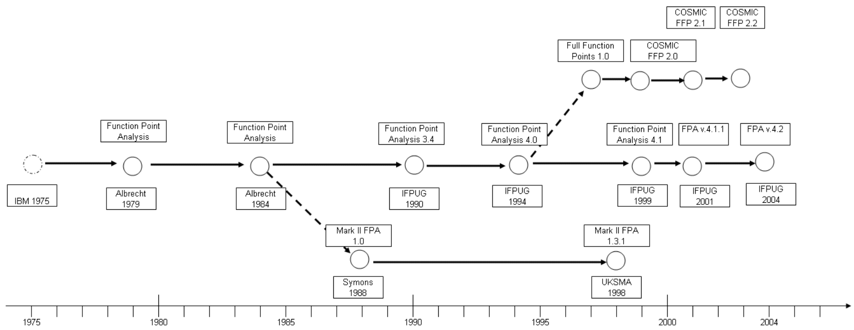



**Figure 1.** Evolution of the main Functional Size Measurement (FSM) methods

COSMIC-FFP [41], adopted in 2003 as ISO 19761 [34], has been defined as a 2nd generation FSM method as a result of a series of innovations, such as: a better fit with both real-time and MIS environments, identification and measurement of multiple software layers, different perspectives (viewpoints) from which the software can be observed and measured, and the absence of a weighting system.

## 2.2. Related Work

### 2.2.1 Functional Profiles and the Size-Effort Relationship

Abran et al. [3] used the 2003 version of the ISBSG repository to build estimation models for projects sized by the FPA method. They defined the concept of a software functional profile as the distribution of function types within the software. They investigated whether or not the size-effort relationship was stronger if a project was close to the average functional profile of the sample studied. For each sample, it was noted that there was one function type that had a stronger relationship with project effort. Moreover, the sets of projects located within a certain range of the average profile led to estimation models similar to those for the average functional profile, whereas projects located outside the range gave different regression models, these being specific to each of the corresponding subsets of projects.

In [4], the impact of the functional profile on project effort was investigated using the ISBSG repository. The ISBSG projects included in this analysis were all sized by the COSMIC-FFP method. For the COSMIC-FFP method [41], a functional profile

[3] Part 1 (14143-1) has recently been updated (February 2007) [28] from its first release [27] (1998).

corresponds to the relative distribution of its four BFC Types for any particular project. It was observed that the identification of the functional profile of a project and its comparison with the profiles of their own samples can help in selecting the best estimation models relevant to its own functional profile.

In [7], the types of functionalities a software system can provide to its users are identified, and a multidimensional measure which involves measuring the functional size of each functionality type is defined. Gencel suggested that experimental studies should be conducted to find the relationship between the functional size of each functionality type and the effort needed to develop the type of functionality that can pioneer new effort estimation methods.

### 2.2.2 Project Cost drivers – the Size-Effort Relationship

In published studies, significant variations in the impact of other project cost drivers have been observed, and therefore a number of experimental studies were performed to investigate their impact on the size-effort relationship. Among the cost drivers investigated, Team Size, Programming Language Type, Organization Type, Business Area Type, Application Type and Development Platform have been found to affect the size-effort relationship at different levels of significance [19][20][21][22][23][25]. Among these, the most significant are reported in [19][20] to be Team Size, Business Area Type and Application Type.

## 3 Data Preparation

In this study, the project data in the ISBSG 2007 Repository, CD Release 10 [10], are used for statistical analysis. This ISBSG Repository includes a large amount of high-quality data on a very wide range of projects. ISBSG Release 10 contains data from 4,106 projects, 117 of which were sized using COSMIC-FFP. The projects cover a wide range of applications, development techniques and tools, implementation languages, and platforms.

Since many factors vary simultaneously, the statistical effects may be harder to identify in a more varied dataset than in a more homogeneous one. Therefore, a series of homogeneous subsets is built for this study using factors which were found to significantly affect the size-effort relationship.

Table 1 shows the filtration process with respect to the project attributes defined in the ISBSG dataset.

The first step was to filter the dataset with respect to the Count Approach attribute in the ISBSG repository to obtain only the projects measured by COSMIC-FFP. This step provided 117 projects, the functional size of which was measured with the COSMIC-FFP method.

The second step was to analyze these 117 projects with respect to the Data Quality Rating (DQR) ISBSG field to keep only the highest quality data for statistical analysis; in the ISBSG dataset, each project has a Quality Tag[4] (A, B, C or D) assigned by the ISBSG reviewers, based on whether or not the data fully meet ISBSG data collection quality requirements. Considering this ISBSG recommendation, 4 of the projects with a D rating were ignored, leaving 113 projects following this filtration step.

The third step was to verify the availability of fields of size by functional type (or BFC) in the data set, for each of the 113 projects from step 2, since these fields are necessary for this study. The verification indicates that this information is not available for 21 of the projects, leaving 92 projects for the next step.

**Table 1.** Filtration of ISBSG 2007 Dataset Release10

| Step | Attribute | Filter | Projects Excluded | Remaining Projects |
|---|---|---|---|---|
| 1 | Count Approach[5] | = COSMIC-FFP | 3,989 | 117 |
| 2 | Data Quality Rating (DQR) | = {A \| B \| C} | 4 | 113 |
| 3 | Rating for Unadjusted Function Points (UFP) | ={A \| B} | 21 | 92 |
| 4 | Application Type | = {Management Information System} | 49 | 14 |
| | | = {Financial Transaction Process/ Accounting} | | 21 |
| | | = {Customization to a Product Data Management System} | | 14 |
| 5 | Business Type | Missing for most of the projects | - | |
| 6 | Maximum Team Size | Missing for most of the projects | - | |

The fourth step was to select the project attributes that were found to significantly affect the size-effort relationship in [19][20] to build more homogeneous subsets out of the 92 remaining projects. While exploring the nature of the relationship, the impact of other factors which were found to affect productivity, were also considered. However, many of these factors are often described, as they are in the ISBSG Repository, as categorical (or nominal) variables on which mathematical operations cannot be carried out directly. To take them into account, subsets must be built for each categorical value of such variables – referred to here as homogeneous with respect to the variable selected.

In this study, Application Type is taken into account to form these homogeneous sub-datasets.

4 A: The data submitted were assessed as sound, with nothing identified that might affect their integrity; B: The submission appears fundamentally sound, but there are some factors which could affect the integrity of the submitted data; C: Due to significant data not being provided, it was not possible to assess the integrity of the submitted data; D: Due to one factor or a combination of factors, little credibility should be given to the submitted data.

5 No further filter has been considered with respect to the COSMIC-FFP versions.

- Application Type
  - Management Information System
  - Financial Transaction Process/Accounting
  - Customization to a Product Data Management System
  - Others (Since the data points for this type were too few for statistical analysis, it was decided to drop them from further analysis)

Thus, in this step (4), 49 projects were selected and distributed among the following three homogeneous data subsets:
- Management Information System = 14 projects
- Financial Transaction Process/Accounting = 21 projects
- Customization to a Product Data Management System = 14 projects

The fifth step is to look into the availability of two other cost drivers:
- Business Type
- Maximum Team Size

However, the values of these attributes (Business Type and Maximum Team Size) are missing for most of the projects in ISBSG Release 10. Therefore, this step (5) was skipped.

# 4 Statistical Data Analysis & Results

The primary aim of this study is to explore whether or not an effort estimation model based on the components of functional size rather than on only a total single value of functional size would improve estimation models.

In this study, the three sub-datasets are first analyzed to determine the strength of the relationship between the total functional size and the development effort by applying a Linear Regression Analysis method. Next, the strength of the relationship between the functional sizes of the COSMIC-FFP BFC Types used to determine total functional size and development effort is analyzed by applying a Multiple Regression Analysis method. These findings are compared to the models representing the relationship between total functional size and effort.

All the statistical data analyses in this study were performed with the GiveWin 2.10 [9] commercial tool and its sub modules.

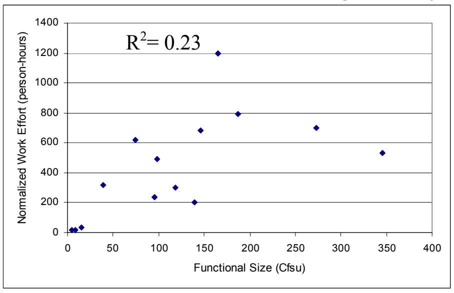
## 4.1 Total Functional Size - Effort Relationship

For the Linear Regression Analysis, the independent variable is Functional Size and the dependent variable is the Normalized Work Effort value from the Normalized Work Effort attribute. These variables are used so that the effort data among the projects that do not include all the phases of the development life cycle are comparable.

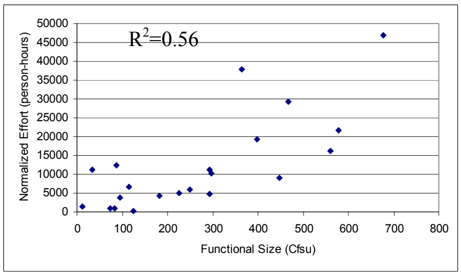
Figure 2 shows the relationship between Normalized Work Effort and COSMIC-FFP functional size.

For the Financial Transaction Process/Accounting dataset, the $R^2$ statistic is better than that for the Management Information Systems and Customization to a Product Data Management System datasets.

a) Sub-dataset 1: Customization to a Product Data Management System




b) Sub-dataset 2: Financial Transaction Process/Accounting




c) Sub-dataset 3: Management Information System

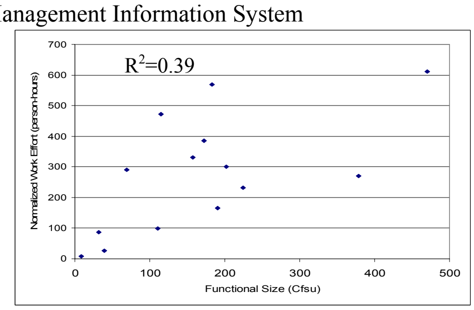



**Figure 2.** The Relationship between Normalized Work Effort and COSMIC Functional Size

A significance test is also carried out in building a linear regression model. This is based on a 5% level of significance. An F-test is performed for the overall model. A $(Pr > F)$ value of less than 0.05 indicates that the overall model is useful. That is, there is sufficient evidence that at least one of the coefficients is non-zero at a 5% level of significance. Furthermore, a t-test is conducted on each $\beta j$ ( $0 \le j \le k$). If all the values of $(Pr > |t|)$ are less than 0.05, then there is sufficient evidence of a linear relationship between y and each xj ($1 \le j \le k$) at the 5% level of significance.

The results of the linear regression analysis are given in Table 2.

**Table 2.** Regression Analysis Results (Normalized Work Effort – Total Functional Size)

| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
|---|---|---|---|---|---|---|---|
| Subset 1: Customization to a Product Data Management System | | | | | | | |
| Functional Size | 3.01454 | 0.51622 | 5.840 | 0.0001 | 0.0001 | 0.0000 | 1.00000 |
| $R^2 =$ 0.23 | | | | | | | |
| | value | prob | | | | | |
| normality test | 3.8843 | 0.1434 | | | | | |
| Subset 2: Financial Transaction Process/Accounting | | | | | | | |
| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
| Functional Size | 46.61200 | 5.48730 | 8.495 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |
| $R^2 =$ 0.56 | | | | | | | |
| | value | prob | | | | | |
| normality test | 5.2770 | 0.0715 | | | | | |
| Subset 3: Management Information System | | | | | | | |
| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
| Constant | 120.95059 | 69.13106 | 1.750 | 0.1057 | 0.0879 | 0.0745 | 0.6000 |
| Functional Size | 0.91522 | 0.33057 | 2.769 | 0.0170 | 0.0012 | 0.0080 | 1.0000 |
| $R^2 =$ 0.39 | | | | | | | |
| | value | prob | | | | | |
| normality test | 1.9550 | 0.3763 | | | | | |

For subsets 1, 2 and 3, the Total Functional Size is found to explain about 23%, 56% and 39% of the NW_Effort respectively.

### 4.2 Functional Sizes of BFC Types – Size-Effort Relationship

The COSMIC-FFP method [34] is designed to measure the functional size of software based on its Functional User Requirements (FURs). In this method, each FUR is decomposed into its elementary components, called Functional Processes. A Functional Process is defined as "an elementary component of a set of FURs comprising a unique, cohesive and independently executable set of data movements" [34]. The BFCs of this method are assumed to be Data Movement Types, which are of four types; Entry (E), Exit (X), Read (R) and Write (W). The functional size of each Functional Process is determined by counting the Entries, Exits, Reads and Writes in each Functional Process, and the Total Functional Size is the sum of the functional sizes of the Functional Processes.

In this study, the Multiple Regression Analysis method [26] is used to analyze the relationship between the dependent variable Normalized Work Effort and the functional sizes of each BFC Type as the dependent variables.

The following multiple linear regression model [26] that expresses the estimated value of a dependent variable y as a functions of k independent variables, $x_1$,$x_2$, ….. , $x_k$, is used:

$$y = B_0 + B_1 x_1 + B_2 x_2 + ..... + B_k X_k \quad \textbf{(1)}$$

where $B_0$, $B_1$, $B_2$, $B_k$ are the coefficients to be estimated from a generic data sample. The effort estimation model can then be expressed as:

$$NW\_Effort = B_0 + B_1(E) + B_2(X) + B_3(R) + B_k(W) \quad \textbf{(2)}$$

where NW_Effort (Normalized Work Effort) is the dependent variable and E, X, R and W are the independent variables representing the number of Entries, Exits, Reads and Writes respectively. In building a multiple linear regression model, the same significance tests as discussed in the previous section are carried out. Table 3 shows the multiple regression analysis results.

**Table 3.** Multiple Regression Analysis Results (Normalized Work Effort – Functional Sizes of BFC Types)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Subset 1: Customization to a Product Data Management System | | | | | | | |
| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
| Read | 6.69258 | 0.96538 | 6.933 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |
| $R^2$ = 0.41 | | | | | | | |
| | value | prob | | | | | |
| normality test | 2.0558 | 0.3578 | | | | | |
| Subset 2: Financial Transaction Process/Accounting | | | | | | | |
| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
| Entry | 220.99324 | 24.61603 | 8.978 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |
| $R^2$ = 0.60 | | | | | | | |
| | value | prob | | | | | |
| Normality test | 6.6034 | 0.0368 | | | | | |
| Subset 3: Management Information System | | | | | | | |
| | Coeff | StdError | t-value | t-prob | Split1 | Split2 | reliable |
| Write | 18.56507 | 2.08722 | 8.895 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |
| $R^2$ = 0.54 | | | | | | | |
| | value | prob | | | | | |
| normality test | 2.7829 | 0.2487 | | | | | |

For subset 1, the Read category is found to explain about 41% of the NW_Effort. For subset 2, the Entry category is found to explain 60% of the NW_Effort. For subset 3, the Write category is found to explain 54% of the NW_Effort.

## 5 Observations

This study has explored whether an effort estimation model based on the functional sizes of BFCs Types rather than the Total Functional Size value would provide better results. Our hypothesis was that the development effort for each of the BFC Types, which provide different user functionalities, might be different.

For the statistical analyses, the dataset of ISBSG 2007, Release 10 [10], was used. Projects measured by COSMIC FFP were selected. While exploring the nature of the relationship between functional size and effort, some factors which are found to most affect the size-effort relationship were also taken into account. At the end of the filtration process, three homogeneous subsets of projects are built based on the Application Types of the projects and with enough data points for statistical analysis.

The $R^2$ statistics were derived from Linear Regression Analysis to analyze the strength of the relationship between Total Functional Size and normalized work effort, and then compared to the $R^2$ statistics derived from the Multiple Regression Analysis performed on the Functional Sizes of the BFC Types and Normalized Work Effort. Increases in $R^2$ values (0.23 to 0.41 for Subset 1; 0.56 to 0.60 for Subset 2 and 0.39 to 0.54 for Subset 3) were observed when the functional sizes of each of the BFC Types are taken into account for effort estimation purposes, instead of the Total Functional Size. The results showed a significant improvement in the modeling of the size-effort relationship in the estimation models for at least two of the subsets.

An interesting observation in this study is that the functional size of a single BFC Type – Reads in subset 1, Entries in subset 2 and Writes in Sub-dataset-3 – can model both Normalized Work Effort and Total Functional Size.

The results of this study indicate that more research is needed to analyze the effect of different BFC Types on effort estimation. The effort required to develop software for different functional domains might be better explained by taking into account the functional sizes of different BFC Types. Further work should also include comparisons with related work performed with the FPA method.

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