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An ERP functional size measurement method delivering time and cost estimates

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Abstract

Background: The implementation of ERP (Enterprise Resource Planning) systems is substantially different than technology orientated software applications e.g. embedded software. The ERP domain is recognized with a high degree of complexity originating from different organizational divisions which is operationalized by a wide set of business processes. These complexities make it very challenging for the effort estimation of ERP implementation projects which often cause these projects to run overtime or over budget. The current project estimation methods do not account for the complexities involved in ERP implementations which lead to inaccurate effort estimates.

Method: In this study we analyze a number of functional size methods which could be used to improve ERP project effort estimations for ERP implementations. We studied nine projects at SAP AG as a focused study for effort estimations. The research was carried out using an action research method while collecting primary data through observations and interviews.

Results: This thesis investigates why the current ERP effort estimation methods fail to deliver accurate estimates while creating a new method which could provide accurate estimates. The COSMIC FSM method is selected as the best fit for ERP effort estimation and used as the basis to create a new method which is used during a focus study at SAP AG. A new FSM method called the COSMIC EPC is created for accurate ERP effort estimations. The new method primarily makes use of business process models (BPM) as input to measure a projects functional size. A supportive toolset is developed to further enhance on the method's capabilities and integration into existing practices. Add-on functionality for the SAP ARIS EPC (business process modeling tool) and SAP ASAP (project management software). The COSMIC EPC method is unique due to its capability to determine the functional size of ERP business processes used as an input for accurate time, cost and effort estimates.

Conclusion: We conclude that when adding new parameters to the estimation methods the accurateness of ERP projects can effectively be improved. The parameters include business process reuse and customization which increase the visibility of ERP process complexity and increase the accuracy involved in ERP effort estimations. The COSMIC EPC method can be used to produce accurate time and cost estimates and improve on the existing expert judgment methods used today.

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Glossary

Word	Description
BPMN	Business Process Modeling Notation
FSM	Functional Size Measurement
BP	Business Processes
BPM	Business Process Model
ERP	Enterprise Resource Planning
RE	Requirements Engineer
PM	Project Manager
IS	Information System
Cfsu	COSMIC functional size unit
Cfs	COSMIC functional size
EPC	Event-driven Process Chains

1. Introduction

Contemporary software development organizations are characterized as sophisticated legal entities with different operational departments. These departments contribute to a set of operational activities with a common objective. The operations are structured and repeated through the means of business processes. These organizations often make use of enterprise solutions to increase their efficiency and reduce the total cost of ownership. Very often, the bigger the organization become, the more complex the processes are. The organizations increase their reliance on enterprise management solutions such as ERP (Enterprise Resource Planning) systems. The success of ERP systems depends on the implementation practices and the understanding of the needs of the organization. Therefore this thesis focuses on the requirements engineering and project management practices during the pre-implementation phase of SAP ERP implementation projects.

SAP ERP projects solve business coordination problems in organizations by implementing a standard set of business functionality packaged as “off-the-shelf packages” within a larger business application. Just like information systems in general, implementations of ERP systems are notoriously difficult by nature – i.e. due to their size, scope, and complexity [1]. ERP RE (requirements engineering) practices focuses primarily on abstracting insight using business processes and data maps [2][3][4]. ERP projects often include adaptation or reconfiguration of standard business processes [2].

The problem addressed in this thesis is the problem of accurate estimation of effort for ERP system implementation during the project planning phase. The complexity associated with ERP system implementations are sometimes overlooked or ignored. Other ERP failures documented in previous work originate from the poor understanding of the project scope, poor estimation of required resources, a poor understanding of the implementation environment and failure due to a high degree of complexity [1][5][6]. Certain effort estimation methods used today are delivering estimates which are not accurate enough and which cause many ERP implementation failures even before the projects have started [7][8]. Providing insufficient number of resources with a poor understanding of the required business processes ultimately demonstrate severe budget and time overruns or a ERP system misaligned with the organizational process needs [9][7][10].

In consequence the research question addressed in this thesis is: *Which method could deliver accurate effort estimations to improve the amount of successful ERP implementations?*

The thesis investigates why the current ERP effort estimation methods fail to deliver accurate estimates. This thesis takes into perspective the methods currently used for ERP estimation “best practices” combined with the most recent research suggestions for quantitative approaches for project size estimation [4][11][12]. The main focus of the thesis is to provide a project estimation method for the SAP ERP vendor and adaptors during an early phase of ERP implementation.

This thesis is aimed specifically for the ERP domain; therefore the approach used in this thesis is not aimed to solve technology related software problems like “embedded systems”. However, the thesis could provide an impact on the Software Engineering domain by providing an alternative view, approach or method for collecting requirements, for example using business process models to elicit, estimate effort and evaluate requirements for business software. Furthermore the thesis results could be used to improve our understanding of the SE domain related to the estimation of complex, cross-organizational and interconnected enterprise systems. The thesis focus on ERP implementations within SAP AG which according to domain experts differentiate itself from the traditional SE practices. This thesis is only concerned about the pre-implementation phase, and focuses on the requirements elicitation phase of an SAP ERP project which excludes the actual implementation practices itself. Only the roles of the project manager and the requirements engineer are considered in this thesis. This thesis is focused on the functional size estimation of ERP implementations as input for accurate ERP effort estimates. The thesis does not take quality requirement into account and derive functional requirements from business processes. Moreover the thesis do include time and cost estimation of ERP projects, but only from the perspective of using functional size measures as input and do not suggest the replacement of financial models.

This thesis is aimed at SAP ERP vendors and adapters which are responsible for SAP ERP projects implementations during the pre-implementation phase. The focused roles include tasks executed by project management and the requirements engineer [13][14][15]. In this thesis we highlight the overlapping role of project management and requirements engineering. In this thesis we argue that the requirements engineer is an important part of effort estimation in the ERP domain (chapter 3.3). Furthermore, the thesis serves an academic audience interested in RE (requirements engineering) and PM (project management) activities for large scale enterprise solutions. In this thesis we aim to contribute knowledge in the field of enterprise software requirements engineering and project management.

This thesis is mainly based on the work performed; by Frank Vogelezang [4], using the COSMIC-FFP for sizing, estimating and planning in an ERP environment. Carlos Monsalve [16] [17] which suggested using FSM (Functional Size Measurement) with Business Process Models and Maya Daneva [11] [18][8][19][20][21] for ERP Requirements Engineering practices, FSM method descriptions and reuse techniques in general.

The thesis is structured containing: The research approach (Chapter 2). a literature review (Chapter 3) which provides the thesis with a foundation to create a new FSM method, a field study of effort estimation practices at SAP AG (Chapter 4), the newly created method and contribution to science (Chapter 5), a evaluation of the suggested method (Chapter 6), the conclusion (Chapter 7), the impact of the suggested method in the industry (Chapter 8), a discussion about the contribution of the research and the alignment with other research (Chapter 9), the thesis Bibliography (Chapter 10) and the appendix (Chapter 11) containing detailed descriptions, diagrams and additional literature used in the thesis.

2. Research Method

This thesis represents a new method addressing a specific problem reported in the industry and includes a focused study with a specific group of users operating at SAP AG.

2.1.Context

This thesis investigates a problem at SAP AG related to inaccurate ERP effort estimations, which is the root cause of many failed ERP implementations. SAP AG is a German company and a leading ERP and business application provider operating worldwide.

2.2.Research design

The research design is explorative, therefore exploring the practices that SAP AG is using in terms of ERP effort estimates. The research methods used in this thesis apply triangulation by including both a qualitative and a quantitative research method [22][23]. The thesis is driven by a qualitative method described in chapter 2.2.3 while using the quantitative method described in chapter 2.2.4. The action research method is used in this thesis to emphasize the social interaction and collaboration between researchers and practitioners [24]. In this research we want to obtain industrial validated results and therefore motivate why we use action research. The thesis is also interpretive and is concerned with the research gaining an in-depth understanding of a particular phenomenon in a real-world setting. The research does not have a hypothesis but make use of themes for guidance as a inductive approach [25]. The result is inductively derived from a focused study at SAP AG.

Action research has been criticized for not creating universal knowledge while only focusing on local realities [26]. In this thesis we attempt to avoid this by articulating and discussing the framework of ideas brought into the study and the analytical generalization of the findings. The strengths of action research are considered to be “an approach for theory and practice to inform each other” and create validated results useful for industry but accepted in academics. An approach to balance action research is to think in two cycles; one cycle to satisfy the research community and one cycle to improve and serve the industrial community [26] as in the case of this thesis.

2.2.1. Primary data collection

The primary data collection for the SAP focus study consists of two ERP project observations and ten interviews where five of them were semi structured interviews at the beginning of the research and five unstructured interviews after the creation of the thesis result.

The observations were the first step to investigate how SAP carries out their effort estimation and which SAP stakeholders and roles are involved in this. The two observations include PM (projects management) and RE (requirement engineering) roles at SAP St.Gallen and SAP Walldorf in an ERP project lifecycle. The non participant observations took a total of 30 days during an ERP pre-implementation phase. The observation results were documented by taking notes of the activities, tasks, communication and tools used by the stakeholders involved during this phase. The observation result was presented in Chapter 4 describing what SAP use and do in terms of effort estimation, Chapter 5 where the observation results provide a framework for creating a new method. The observations are also used to validate the results delivered from the interviews (qualitative evaluation) and (quantitative evaluation) discussed below. The observations provide the thesis with information related to "how" we interpret what SAP is doing. The observation notes were transcribed and coded using Nvivo 9 which provides the research the opportunity to create themes aligned with the practices of the action research method.

Secondly, there were five semi structured interviews which together represent five countries in Europe (Switzerland, Netherlands, Sweden, UK and Germany) from the perspective of two disciplines PM and RE per country. The interviews were semi structured to allow the interviewee time to elaborate on a certain topic of importance to the question [25]. The interview questions that were used in these interviews are available in the appendix chapter 11.1. The interviews presented as the "what" SAP says they do in terms of ERP effort estimations are presented in Chapter 4. Step 1 observations and step 2 semi structured interviews provide the thesis with information needed to create a new method described in Chapter 5. The interviews were audio recorded and varied in time from 60 to 120 minutes. The interviews was then transcribed and coded in Nvivo.

Thirdly, there were five unstructured (follow-up) interviews, one representing each sample country, whereby the same individuals were contacted to discuss and validate the use of the newly created method and supportive tools presented in Chapter 5 and evaluated in Chapter 6. In these interviewees the participants were introduced to the COSMIC EPC method and presented with a example describing the use and result of the method. After the introduction the unstructured interviews still had two main themes to direct the discussion which is available in the appendix chapter 11.1.2. The interviews were audio recorded and varied in from 80 to 120 minutes. The interviews was then transcribed and coded in Nvivo.

Fourthly, to generalize further, six ERP adaptors were approached and interviewed. The six interviews were structured in two parts. The first part was semi-structured with the same interview questions and structure as mentioned in step 2. The interviews were used to determine the differences and similarities which either support or reject the argument displayed in a qualitative analysis of the method provided in Chapter 5 and evaluated Chapter 6. The second part of the interview was similar to the SAP follow-up interviews (step 3) to generalize the use of the suggested method further. The interviews were audio recorded and varied from 90 to 120 minutes. The interviews was then transcribed and coded in Nvivo.

Lastly, the research includes two unstructured interviews with two topic experts actively writing and publishing material related to ERP effort estimation. These interviews were unstructured and used to verify the research results while stimulating a dialogue to provide feedback of the new COSMIC EPC method and supportive toolset. The interviews were audio recorded and varied from 90 to 120 minutes. The interviews was then transcribed and coded in Nvivo.

The following table provides a list of the primary data collection events.

Organization	Department	Method Type	Location	Method of Primary data collection	Participants title
interviews at SAP AG					
SAP	Development	Participation Observation	Walldorf - Germany	Observation	Requirement Engineer
SAP	Development	Participation Observation	St.Gallan - Switzerland	Observation	Project Manager
SAP	Development	Face-to-face	Walldorf - Germany	Interview	Project Manager
SAP	Development	Face-to-face	Walldorf - Germany	Interview	Requirement Engineer
SAP	Consultancy	Face-to-face	London- UK	Interview	Project Manager
SAP	Consultancy	Face-to-face	Zurich - Switzerland	Interview	Project Manager
SAP	Consultancy	Face-to-face	St.Gallan - Switzerland	Interview	Requirement Engineer
SAP	Consultancy	Face-to-face	Den Bosch - Netherlands	Interview	BI Project Manager Requirement Engineer
SAP	Consultancy	Telephone	Gothenburg- Sweden	Interview	Project Manager
SAP	Consultancy	Telephone conference	London- UK	Follow-up Interview	Project Manager
SAP	Research	Face-to-face	St.Gallan - Switzerland	Follow-up Interview	Senior Researcher
SAP	Consultancy	Telephone conference	Walldorf - Germany	Follow-up Interview	Requirement Engineer
SAP	Research	Face-to-face	St.Gallan - Switzerland	Interview	Senior Researcher
SAP	Consultancy	Face-to-face	Den Bosch - Netherlands	Follow-up Interview	BI Project Manager Requirements Engineer
SAP	Consultancy	Telephone conference	Gothenburg- Sweden	Follow-up Interview	Project Manager
Other- ERP adaptors					
Logica	Consultancy	Face-to-face	Baden - Switzerland	Interview	Project Manager
Accenture	Consultancy	Telephone conference	Zurich - Switzerland	Interview	Project Manager Requirements Engineer
KPN	Consultancy	Telephone conference	Gravenhage - Netherlands	Interview	Requirements Engineer
IBM	Consultancy	Telephone conference	Stockholm - Sweden	Interview	Requirements Engineer
D1 Solutions	Consultancy	Face-to-face	Switzerland	Interview	Project Manager
Accenture	Consultancy	Face-to-face	Amsterdam - Netherlands	Interview	Project Manager / Requirements Engineer
Academics (Topic experts)					
Gothenburg University	Academics	Telephone Conference	Gothenburg- Sweden	Interview	Researcher
Twente University	Academics	Face-to-face	Enschede - Netherlands	Interview	Researcher

Table 1: Primary Data Collection

2.2.2. Secondary literature

The secondary literature collection is based on a literature review that include a wide set of keywords, topics, methods and theories which could be associated with the problem domain related to ERP effort estimation. Figure 15 in the appendix contains the keywords used during the literature review. The sources used in the thesis include books, academic articles, industry reports, websites and seminar papers.

2.2.3. Qualitative approach

A qualitative method was used during the data collection of the interviews and observations listed above in Table 1. The empirical data were analyzed by comparing the strength and weaknesses of the FSM methods to analyze which method could be the best fit for ERP effort estimations. The empirical data were transcribed for analysis by coding common themes, ideas or problem nodes. An evaluation scorecard was used (as displayed in Chapter 6.1). There were mainly three stages where the empirical data were analyzed: The first stage was to analyze what method SAP AG is currently using. The second analysis was conducted to determine which method could be a promising fit for SAP AG which was executed before creating the new method and the third analysis was executed to test the new method and generalize the application of this method.

2.2.4. Quantitative approach

A quantitative approach was used for the evaluation of the current SAP effort estimation method and the suggested method delivered in the thesis. The quantitative approach was carried out using historical data of nine ERP projects in a simulation to evaluate the accurateness of the new method. Relationship patterns and statistical analysis allow for a quantitative approach to validate and explore the effects and causes such a method could have. The quantitative approach is purely to support the qualitative research approach to further generalize and validate the qualitative results. Finally the research compares the accurateness of the existing effort estimation method versus the newly suggested method created in this thesis by using the nine ERP projects data. The estimate times delivered by the methods are measured against the ERP projects actual delivered times.

2.2.5. Action research

The action research is conducted in cycles. In this thesis there was one cycle due to the time restriction of the research. Future research could be carried out in more cycles building on top of the thesis results for example a pilot study of the new method within the ERP industry. The action research approach used in this research as described by O'Brein [27] contains the following steps: A diagram is available for the action research in the appendix Figure 19.

- Diagnosing the problem area: This step includes diagnosing the ERP environment, stakeholders involved and methods used for ERP effort estimation. This step mainly relate to a combination of the state-of-the-art Chapter 3 and the effort estimation practices at SAP AG Chapter 4.
- Action planning: This step considers alternative courses of action. Different approaches and methods exist to explore the problem domain. In this thesis we analyzed and compared different FSM methods as displayed in Chapter 3.

- Taking a specific course of action: Based on the analysis of the FSM methods, the research followed one FSM method and investigate how this could solve the problem. The method most fitted to the ERP environment is used to create a new method described in Chapter 5.
- Evaluating and considering the causes and consequences of the action: The research use both interviews and observations with a focus study to evaluate the suggested effort estimation method and supportive tools delivered in this thesis in Chapter 6.
- Specifying learning: This concerns identifying the lessons learned and applying it to a wider audience. The thesis makes use of the focused study to further generalize the method to a broader field and explore the potential impact this could have on the industry itself described in Chapter 8.

2.3.Validity of results

The validity is concerned with whether the findings are reliable. In this section we discuss the possible threats of validity and followed the validity categories are suggested by [28]. A detailed list of the threats of validity is available in the appendix chapter 11.2.

2.4.Reliability of the study

Inter-Observer Reliability [29] was used to cross test the reliability of different empirical data by using different data collection methods such as interviewees and observations. Furthermore the study includes different perspectives (PM and RE) from domain areas such as industry and academics. In this case we check which category (node) each contribution falls in and then calculate the percent of agreement. This gives us an idea of how much agreement exists between the categories and nodes.

Test-Retest Reliability [29] was used to retest the reliability where we administer the same test to the same sample on two different occasions. In this case we asked the same question in another way in the beginning of a follow-up interview.

3. ERP effort estimation – a literature review

The thesis investigates which method could improve accurate effort estimations for SAP ERP implementations. In this section we perform a literature review to explore what method can be used. Before addressing that problem we describe the ERP implementation environment, lifecycle, tasks and actors involved.

3.1.The pre-implementation environment

The ERP pre-implementation phase is described as the phase where an ERP vendor or adaptor instructs a pre-sales, project manager or requirements engineer consultant as part of the process to determine the size of a new project to estimate the project time and cost [30][2]. This phase of the project life cycle is very often under-valued with a strong influence on the success or failure of an ERP project [5][21]. During this phase the client expect a quotation or estimate from the ERP vendor or adapter or sales representative [21]. The importance of this estimate is twofold. For the client of the ERP vendor or adopter it is used as a comparison and reliability check to benchmark service providers. Very often ERP tenders are rejected due to cost (extensive over estimation) or unrealistic proposals (under estimation). The latest eposes evidence to bear the highest amount of risk and sometimes leads to law suits such FoxMeyer vs. SAP (ERP vendor) and Accenture (ERP adaptor) [31].

3.2.The Enterprise System Lifecycle

The ERP lifecycle is considerably different from the well-explored "classical" software engineering lifecycle. Beyond the ordinary phase of defining project objectives, requirements elicitation analysis and developing, Enterprise Systems (ERP) implementation contains the two main phases of system selection and system configuration [32]. Unlike "classical" software engineering where software requirements and specifications are followed by the architectural design and coding, Enterprise Systems has already a set architecture where requirements and specifications are followed by the selection of functionality in the form of business scenarios and system configuration (customization) where applicable.

3.3.Requirements elicitation

This thesis focuses on the requirements elicitation phase of the ERP lifecycle. In this thesis we refer to the requirements engineering as a role or position filed by a group or an individual executing the task or part thereof; collecting, prioritizing, specifying, and modeling requirements as a first input for project planning. From an academic perspective there might be different views on the exact roles covered by requirements engineering, where the first view resemble a clear separation between the tasks of a requirements engineer (RE) and project management (PM). From another perspective the academic literature (where the results were very often based on industry observation and expert interviews) [33][34][21], indicate the overlapping roles between the project management and the requirements engineer roles and mention that these tasks might be performed by either the RE ,PM or both, depending on the organization and project [13][14][15]. At SAP AG requirements elicitation and effort estimation takes place before a project manager is selected or assigned to a project. Thereafter the result determined by the RE may be used by sales for communicating project costs and time estimations. Further discussions and project changes are often discussed and negotiated with a PM.

3.4.Requirements modeling

Today it is known that BPM (business processes models) are used during the requirements elicitation phase of Enterprise Systems [13]. BPM enables different stakeholders to communicate a common understanding of an organization's operational process. Davenport [35] define business processes as "a set of logically related tasks performed to achieve a defined business outcome." An enterprise can be analyzed and integrated through its business processes. Hence the importance of correctly modeling its business processes [36]. The BPMN (Business Process Modeling Notation) is a standard for modeling business processes. Business Process Management is concerned with managing change to improve business processes and would be the first place to introduce customization of existing processes [37]. Vogelzang [4] wrote that a detailed business process model is sufficient to make a detailed functional size measurement for effort estimation.

Now that we have investigated the ERP implementation environment, lifecycle, tasks and actors involved, we can move forward to investigate which method could improve accurate effort estimations of SAP ERP implementations.

3.5.Effort estimation models

Many different studies comparing effort and cost estimation models for software have been published, including [38][39][40] [41] where data sets were used of various sizes in different environments. Many of these studies main conclusions were that these models perform poorly when applied to other environments [42][43], therefore we need to consider the method to fit the ERP environment as described in chapter 3.1 to 3.4 carefully.

Kemerer [42] used 15 projects from business applications and compared four models: SLIM [39], COCOMO [38], Estimacs [39], and Function Points (FP) [40]. Kremerer found that the function point based prediction models outperformed all the other models. Srinivasan [44] include in their comparison: regression trees, artificial neural networks, function points, the COCOMO model, and the SLIM model. They used the COCOMO data set (63 projects from different applications) as a training set and tested the results on 15 projects, mainly business applications. The regression trees outperformed the COCOMO and the SLIM model. They also found that the function point based prediction models outperformed regression trees [45].

3.6.Function Point estimation

Based on the findings above (Chapter 3.5) we now look at functional point estimation methods. Cutting [3] wrote that a function point is a unit of measurement to express the amount of business functionality an information system provides to a user. Furthermore, the cost usually expressed in terms of currency or time of a single unit is calculated from past projects. Function points are the units of measure used by the differentiated Functional Size Measurement (FSM) methods. FSM method dates back as far as the 1970's and has been developed in different forms and models as indicated in the appendix Figure 16. This figure indicates how FSM methods have evolved through time building on the strengths of the previous FSM method generations.

Currently there are very few or no specific studies that compare the accurateness of different FSM methods in a quantitative comparison for the ERP domain. Therefore we focus on a qualitative review of the strengths and weaknesses of the FSM methods followed by an analysis to compare the FSM methods best fitted for the SAP ERP domain.

3.7.FSM methods (Strengths and Weaknesses)

Method/ Feature	Strengths	Weakness
IFPUG	- It is the most known FSM method in the software industry, with the biggest membership count. - It has a proficient track record for accurate functional size calculation used for estimation purposes. - External comparability of results. - Consolidated and diffused technique, with counting rules regularly monitored by International bodies. -Provide training and certification to ensure the proper use and quality of the method. - It is the basis upon which many other methods originated from. - It is ISO credible and standardized. - It is used mainly for business application software.	- The method's basic concepts date from the late 1970's there might be limited relevance to modern practice in Requirements Engineering and Software development. - Lacks credibility for large complex projects due to the limited size scale (the measure is a nonlinear, ordinal scale) - Project Estimation cannot be done before until the analysis phase - The method's manual and guidelines is not free and more difficult to access. - The method is much more complicated than other FSM methods, therefore the method increase complexity and the time to perform the sizing initiatives. - There might be the tendency to over engineer on an estimation basis, which could defeat the main purpose of having an estimation method as a start.
MK II	- It is ISO credible and standardized.	- High degree of effort to complete logical transaction types (the lowest level business processes supported by a software application) to determinate the size - Mainly for business application software. - Needs adaptations for other types of software. - There might be the tendency to over engineer on an estimation basis, which could defeat the main purpose of having an estimation method as a start.
COSMIC	- Designed to measure both business application and real-time software, in multi-tier, multi-layered architectures - The method's basic concepts are aligned with modern software engineering methods such as UML, ARIS, but independent of any one method - Measurement can be embedded in typical software development practices, minimizing the cost of data collection. - It can be applied in early stage of a project - COSMIC can measure the size of software from the views of end users and developers. - The method leans to the opportunity for automated size measuring. - The method is yet accurate but simplistic in nature, easily comprehendible with a lower degree of effort. - It is ISO credible and standardized. -Might be considered less complex in relation to the IFPUG methods.	- Assumes availability of the knowledge of a developer to determinate the size. -No accredited training provided yet. - COSMIC is a recent developed method which still needs to be integrated "popularized" within academics.
PSU	- Fast and quick size estimation. - Following a differentiated technique which	-Lower level of credibility in terms of size calculation, estimation, verification of correlated

	don not requested FPA knowledge - Project estimation can be done before the analysis & design phase	“standard” ISO complaint techniques - The result is predicted by experience and analogy which might be influenced by a personal bias opinion. - The technique is still experimental in nature and can only be used by expert with vast amount of experience in the specific software domain, therefore lack as a generalizable sizing method.
FISMA	- It is designed to be applicable to all types of software. - It is ISO standardized. - The method guide is easily accessible.	- It has only been standardized quite recent, therefore it is not widely used. - It is focused on application oriented services, and is limited to a specific application domain. - The method’s manual and guidelines is high-level and provide little guidance to follow a complex approach. - The method increase complexity and the time to perform the sizing initiatives.
NESMA	-The NESMA method is similar to the IFPUG method. It differentiates itself in terms of the counting guideline. -The NESMA method is less complex and a simplified IFPUG method. The method is easier to apply and require less effort. -The NESMA method distinguishes between project size (which can have a fractional value) and application size (which is always a whole number), so gives more information. - It is ISO credible and standardized.	-NESMA’s method manual is not available for free. - The NESMA approach is still lending itself to over engineer sizing efforts.

Table 2: FSM method Strengths and Weakness Comparison

3.8.FSM analysis

A comparative analysis was performed using the following units of measure to establish which FSM is most suited for the ERP environment:

Unit of measure	Suitability to the ERP domain (Score)
1. Method membership count	A method with a higher number of members score higher.
2. Method certification	A method that offers certification will score higher.
3. Method documentation accessibility	A method that contain documentation and instructions which is easily accessible score higher.
4. Method recognized and standardized (ISO/IEC)	A standardized method score higher.
5. Method guidelines availability	A method with clear guidelines score higher.
6. Applicable application of the method in the ERP PL (Project Lifecycle)	An applicable phase for a FSM method is in the early stages of the pre-implementation phase, the execution of the method at a earlier phase score higher.
7. Software Domain (BU – Business application, TS – Technology based software)	The FSM methods created and tested in the business application domain score higher.
8. Complexity of applying the method	A method which is less complex to execute score higher.
9. Effort required applying method	A method that requires less effort score higher.
10. Relevance to modern practices and updated	A up-to-date method score higher.

methodology	
11. Suitable project size of the specific method	A method which is created or tested for large project sizes will score higher.

Table 3: Units of measure

Table 4 provides a qualitative analysis to compare the FSM methods (based on the unit of measure listed above) to select the method most suitable for ERP effort estimation.

Method	Membership	Certification	Accessibility	Standardized	Guide lines	Applicability	Domain	Complexity	Effort	Modern Practice	Project Size
MK II	√√	X	X	√√ (ISO IEC)	√	√√ (Early in PL)	√ (BU)	X (Complex)	X (Max)	X (Outdated)	√ (Average)
COSMIC	√	X	√	√√ (ISO IEC)	√	√√ (Early in PL)	√√ (BU& TS)	√ (Moderate)	√ (AVG)	√√ (Latest)	√√ (Large)
PSU	X	X	X	X	X	√√ (Early in PL)	√ (BU)	X (Complex)	√√ (Low)	√ (Updated)	X (Small)
FISMA	X	X	X	√ (ISO IEC)	√	√ (Middle of PL)	X (TS)	√ (Moderate)	X (Max)	√ (Updated)	√ (Average)
NESMA	√	X	X	√ (ISO IEC)	√	√√ (Early in PL)	X (TS)	√√ (Simple)	X (Max)	√ (Updated)	√√ (Large)
IFPUG	√√	√√	√	√√ (ISO IEC)	√√	X (Late in PL)	x (TS)	X (Complex)	X (Max)	√ (Updated)	√ (Average)
X-low / √ - average / √√ - high score											

Table 4: FSM Method analysis table

The following Table 5 provides a quantitative overview of the analysis in Table 4 which provides a total score per FSM method.

Method	Mem	Cert	Acces	Stad	Guid	Appl	Dom	Comp	Effo	Mod	PS	Total Score
MK II	2	-1	-1	2	1	2	1	-1	-1	-1	1	4
COSMIC	-1	-1	1	2	1	2	2	1	1	2	2	12
PSU	-1	-1	-1	-1	-1	2	1	1	2	1	-1	1
FISMA	-1	-1	-1	1	1	1	-1	1	-1	1	1	1
NESMA	1	-1	-1	1	1	2	-1	2	-1	-1	2	4
IFPUG	2	2	1	2	2	-1	-1	-1	-1	1	1	7

X = -1 / √ = 1/ √√ = 2

Table 5: FSM Method score table

3.9. Reason for selecting the COSMIC method

In the section we provide a detailed discussion on our motivation for choosing the COSMIC method and explain why the COSMIC method is a good fit for the ERP environment:

1) *Applicable to the business application domain.* We decide to use the COSMIC method due to its generic character applicable to several software domains. The COSMIC method is compatible with modern software engineering concepts and is approved as an International Standard FSM method. The COSMIC FSM is applicable for business applications.

2) *Flexibility in term of the data models or process models used for function point estimation* The COSMIC method account for a basic set of counting rules which could be used with a wide variety of ERP data/process models. The COSMIC method v3.0 is relatively independent of the structure of the model. If some parts of the data model are not known it is still possible to deliver an accurate functional point count. Vogelezang [4] also mentioned that in the pre implementation phase not all process models are accounted for within an ERP

project. However Dumks [46] also mentioned that: "the description of the process is detailed enough to classify a process into one of the four categories of the refined approximate COSMIC".

3) *Reduced effort and complexity in terms of functional point counting.*
Where the IFPUG FPA method presents a set of complicated rules and counting instructions (five factors of scale) that are platform dependant, mostly associated to technology implementation systems (embedded systems) the RE use tremendous amount of effort and need allot of experience to carry out the FSM. This defeat the purpose of an early sizing estimate. On the other hand the COSMIC method is simplified, while accommodating different platforms, with a reduced amount of effort and with less complexity.

4) Specify different measurement viewpoints.
The first generation methods like IFPUG-FPA, MARK II FPA and NESMA-FPA, consider only a specific stakeholder view related to those of the end user when carrying out a specific measurement. This does not account for the full scope of functionality, therefore ignore the functional points which does not have a direct interface. The main disadvantage of this is that it does not always cover all the system's functionality [47]. In contrast the COSMIC method account for both the interfaced and supportive processes therefore represents the views of both the end users and developers [47].

5) *Process change sensitivity.*
The COSMIC method captures functional size variations of individual functional processes much better than the 1st generation IFPUG FPA method. The IFPUG FPA method is less sensitive to functional process changes (customization) encountered in real-time and business software Xunnmei, Guoxin and Hong [48] [49]. Brehm et al. [50] present the broad variety of customization options which affect the functional processes in an ERP project. In this study they discuss the ability of the COSMIC method, which flexibly handles the variety of ERP options, making it easier to measure possible changes.

The following section presents the basic logic and use of the COSMIC FSM method, which will be used as the basis in the new method presented in chapter 5. A more detailed description is available in the appendix Figure 17.

3.10. Using the COSMIC FSM method

The COSMIC-FSM method distinguishes between four different types of data movements. Each data movement counts one functional point:

- **Entry** – An entry is a data movement that moves a data group from a user across the software boundary into the functional process where it is required.
- **Write** – A write is a data movement that moves a data group from inside a functional process to persistent storage.
- **Read** – A read is a data movement that moves a data group from persistent storage to within the functional process, which requires it.
- **Exit** – An exit is a data movement that moves a data group from a functional process across the software boundary to the user that requires it [4].

The following chapter describes the current effort estimation method and processes used by SAP AG.

4. Effort estimation at SAP AG

This chapter includes a description of SAP´s tools, method and processes used for effort estimation. The study include a review of SAP documents, notes taken during two implementation observations and interview data collected at SAP Germany, Netherlands, UK, Sweden and Switzerland. This chapter starts with the introduction of SAP´s current toolset. This will help the research investigate the activities related to ERP effort estimation at SAP.

4.1.The ERP implementation approach

The Accelerated SAP (ASAP) is SAP's standard implementation project management approach. The ASAP approach provide a guideline to accommodate repeatable and successful approaches used to implement the ERP SAP solution [51]. The specific tool used by SAP AG relevant to this thesis are further described as the SAP Solution Manager as part of the ASAP approach.

4.2.The ASAP Solution Manager for PM

The SAP Solution Manager has functionality outlined for PM. It has specific functions for establishing global templates and support implementations, and for rolling out template-based projects which encourage ERP requirements reuse [52]. This tool facilitates the business-process structures with various levels of detail which is most relevant for the opportunity to introduce a FSM. A RE can upload each business scenario and its related business process in a flexible way that allows the PM to keep track of the changes and customizations, while accounting for the customization in the effort estimates [52].

4.3.ARIS EPC Business Process Modeling for RE

SAP AG uses the ARIS EPC modeling framework and tool to visualize and model clients business processes in the pre implementation phase of an ERP implementation. ARIS (Architecture of Integrated Information Systems) is a modeling tool for enterprise modeling and for the RE to communicate process logic and functional requirements [53]. SAP document business processes in the form of ARIS models to demonstrate the objects included in the boundaries of the software, the flow and sequence of events in one diagram.

4.4.The SAP effort estimation model

SAP in general uses a template for calculating effort. The functional effort is grouped as business scenarios or functionality representing the business scenarios. Currently SAP uses the “expert judgment” principle to evaluate the effort in time per BP.

The estimation template for SAP is based on effort in person days. These efforts are delivered by a geustimate (a combination between an estimate and a guest) value derived from using an expert judgment method. These values would be distributed to process scenarios representing certain functionality. Furthermore the effort per business scenario is derived from a (formula) calculated key figure. The key figure *Expected effort* (derived from a best case, realistic and worse case geustimate) plus an effort reserve forms the basis to estimate the effort per functional value.

TOTAL:	with Effort Reserve	1001					39
PERCENT of DEV.	w/o Effort Reserve	0	Best Case	Realistic	Worst Case	Weighted	Effort Reserve
Work Package Function	Skills	Total per Function	Realization Net Effort w/o Schedule Reserve SR			Expected Effort	229%
		1001	243	324	543	393	39
		0				0	0
		0				0	0

Figure 1: SAP Estimation Template

The total amount of effort comes from a series of key figures. In this case the effort is only estimated person days. The estimation in time per business scenario (Level1) is provided by the RE. The PM use this inputs to evaluate the total project duration and budget. The PM use the key figures provided by the RE broken down in this template into *Best case*, *Realistic and Worst Case* effort needed for the implementation of a certain business scenario.

The following steps and formulas are used to calculate the expected project effort.
Expected Effort with Effort Reserve = Expected Effort (Weighted) + effort reuse.

The Expected Effort below display 3 options depending on the RE input in terms best-case, realistic and worst case. The IF option is used to determine which values to use.

Step 1: The first step is to determine the validity of the distribution between best case, realistic and worst case. If the values Best, Realistic and Worst Case vary in value of 100 (or greater) after using the (ROUND) function it will add up all three values together and divide it by 3.

Formula:
Expected Effort = ROUND ((Best Case + Realistic Case + Worst Case)/3

in according to option	Best Case	Realistic	Worst Case	Weighted	Effort Reserve
Expected Effort with Effort Reserve	Realization Net Effort w/o Schedule Reserve SR			Expected Effort	229%
220	100	200	300	200	20

Figure 2: Expected Effort "Expert Judgment"

Step 2a: If there is no explicit difference between the realistic gestimate and the best-case key figure and between realistic gestimate and worst case the formula ignore the realistic key figure and therefore use the best case plus worst case divided by two.

Formula:
Expected Effort = ROUND ((Best Case + Worst Case)/2

in according to option	Best Case	Realistic	Worst Case	Weighted	Effort Reserve
Expected Effort with Effort Reserve	Realization Net Effort w/o Schedule Reserve SR			Expected Effort	229%
385	100	110	600	350	35

Figure 3: Weighted Expected Effort "Expert Judgment"

OR Step 2b: Otherwise if there is either no best case or worst case completed the formula use the Realistic value.

Formula:
Expected Effort = Realistic Case

in according to option	Best Case	Realistic	Worst Case	Weighted	Effort Reserve
Expected Effort with Effort Reserve	Realization Net Effort w/o Schedule Reserve SR			Expected Effort	229%
220	100	200		200	20

Figure 4: Realistic Expected Effort "Expert Judgment"

The reserved effort is hard coded to count as a buffer of around 10% of the expected effort value.

Step 3: The effort reserve are calculated, the rule of thumb here is that the Effort reserve are 10% of the value of the expected effort. When added together (summed-up) they result in the; Expected Effort with Effort reserve.

In conclusion the current estimation practice at SAP judge an approximate time associated with a certain business process scenario.

5. The COSMIC EPC method and supportive tools

In this chapter the thesis display a new FSM method more suited for ERP effort estimates. The new method is based on the logic of the original COSMIC FSM method described in Chapter 3. The new functional size method is called the COSMIC EPC method.

5.1. The COSMIC EPC method overview

The following Figure 5 describes the basic use of the suggested ERP functional size method. The COSMIC EPC method use Business Process Models (BPM) as an input, and convert the BPM into Cfs (COSMIC functional size) points as output which is used for effort estimations.

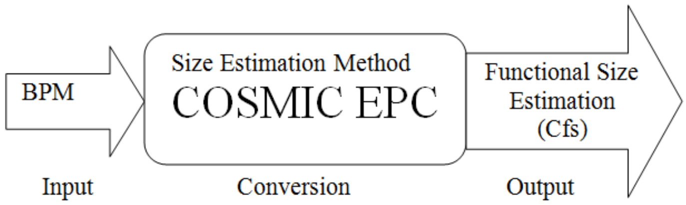


Figure 5: COSMIC EPC method

Figure 6 display an improved COSMIC EPC method taking functional reuse and modification (customization) parameters into account. The COSMIC EPC method makes use of the Cfs points to deliver accurate time and cost estimates as output.

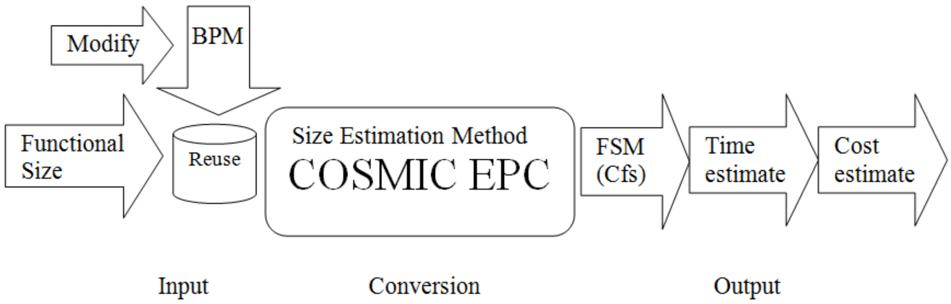


Figure 6: COSMIC EPC version 2 and ASAP prototype

In practice the COSMIC EPC method could be applied to the ARIS models which results in Cfs points. The Cfs is then used, sorted and displayed in the SAP ASAP Solution Manager. This thesis provide a prototype with the COSMIC EPC method applied to the ASAP solution manager as an approach to capture, convert, arrange and calculate the functional size of business scenarios (with its related business processes and process steps). The business scenarios are stored as templates in a repository in its most basic and generic form. The scenario templates can then be used and adapted for a certain environment in different projects. These projects can then account for process reuse and customization in the form of the functional size. The functional size is then used to calculate the time and cost estimates.

5.2. The COSMIC EPC method description

This section describes the COSMIC EPC method in detail. Here we describe the use of business processes and the conversion rules of converting the BPMN into ARIS models. Furthermore, this section describe the rules for applying the COSMIC EPC method to the ARIS and BP models which then provide the functional size associated to a business scenario. The functional size per process step (lower level 3 detail) is then used within the COSMIC EPC model presented as a excel workbook and later developed as add on functionality into the (SAP) ASAP tool. The COSMIC EPC model incorporates process reuse and customization which is used to calculate a conversions rate which weight the Cfs of a certain project against the generic business scenarios template provided by the ERP vendor. Finally this is used in a formula to calculate the time and cost estimate.

5.2.1. Business Processes Models

Business process (BP) models are designed to be useful for documenting, communicating, and improving organizational business processes. They are also used by software engineers and business analysts to gather the software and system requirements from the early stages of a development process [19][32][6]. A BP model may therefore be a valuable source of information for FSM [17]. It was not until recently that the use of BP models for COSMIC FSM has been studied [4]. This thesis complements the results given in [4] by creating the rules for mapping the COSMIC ERP concept to the Business Process Modeling Notation (BPMN) constructs.

5.2.2. Business process scenario structure

Figure 20 in the appendix demonstrate the structure of a business scenario which is accommodated by underlining business processes. The business processes has related process steps. The total size of the business scenario is always equal to the sum of its underlying business processes with its related process steps.

5.2.3. SAP business scenario example (Order-To-Cash)

In the following part of the thesis we make use of the Order to Cash scenario to demonstrate how functional size estimation can take place using business scenarios.

The Order-to-Cash process scenario is used throughout the thesis in a focused study. The emphasis is not on the specific Order-to-Cash scenario itself, but is only used to demonstrate how a specific scenario can be used with its underlying business processes and process steps. A visual demonstration of the structure of the Order-to-Cash business scenario is presented in Table 29. By focusing on one scenario it provides the opportunity for a comparative analysis. Figure 25 in the appendix present the Oder-to-Cash scenario displayed in the BPMN 1.2 format.

5.2.4. Converting the BPMN into ARIS EPC Models

This section demonstrates the conversion of a BPMN 1.2 model into the ARIS EPC model. Furthermore, BPM rules are created to guide a user with a logical set of steps for BPMN to ARIS conversion. Please note the images used in the examples are only used to demonstrate the rule and are found in the appendix.

Modeling Rule BPMN1. Consider any logical instruction set that is worth detailing as a separate BP, for example the Enterprise swimlane. For a visual example please view Table 20 in the appendix.

Modeling Rule BPMN2. Represent any external ERP component that interacts with the measured software as a secondary pool. For a visual example please view Table 21 in the appendix.

Modeling Rule BPMN3. Represent any user of the software as a secondary pool (external user) or as a lane in the main pool (internal user). For a visual example please view Table 22 in the appendix.

Modeling Rule BPMN4. Avoid representing a sequence flow between lanes or a message between pools when that flow or message is only aimed at indicating a possible end to the workflow. For a visual example please view Table 23 in the appendix.

Modeling Rule BPMN5. Any modeling construct that requires retrieving or writing relevant data from/to persistent storage should be associated with a data object. For a visual example please view Table 24 in the appendix.

5.2.5. Conversion logic between BPMN and COSMIC EPC

In the following Table 6 we display a summary of the conversion logic between the BPMN ARIS and COSMIC EPC.

ARIS EPC	**BPMN 1.2**	**Content Logic**
Functional User	Lane and pool	The entities that interact with the use of the suggested functionality.
Boundary	The border of the Business Scenario. The swim lane of a BP	The functional area of the ICT solution.
Functional Process	Pool	The functionality that represent a certain business scenario.
Triggering Event	Start Event	The starting point of the business scenario.
Data Group	Data Object entities	A business object between pools. When data storage need to be accessed.
Data Movement	Data Objects flow	Process flow
COSMIC EPC	**BPMN 1.2**	-
1) Entry	An incoming process sequence flow.	Processes in-flow from another Business Process.
2) Exit	An outgoing process sequence flow.	Processes out-flow into another Business Process.

Data access	Data Objects activity	Document flow
3) Read	An upstream association with a data object	Reading of data/information within a Business Process.
4) Write	An downstream association with a data object	Writing of data/information within a Business Process.

Table 6: BPMN 1.2 conversion to ARIS and COSMIC EPC logic

The table above demonstrates the logic for both the ARIS EPC and BPMN format, while providing the opportunity to use both model types as input for the COSMIC EPC method.

5.2.6. Applying the COSMIC EPC into BPMN 1.2 and ARIS EPC

This section present the transformation rules of applying the COSMIC EPC method to the BPMN 1.2 and ARIS EPC models. The images should only be used to demonstrate the rules. The importance is to identify in which situation to apply the data movements.

Modeling Rule COSMIC1. **Entry** – An entry is a data movement that moves a data group from a user across the software boundary into the functional process where it is required. The movement is marked with “E”. For a visual example please view Table 26 in the appendix.

Modeling Rule COSMIC2. **Write** – A write is a data movement that moves a data group from inside a functional process to persistent storage. The movement is marked with “W”. For a visual example please view Table 27 in the appendix.

Modeling Rule COSMIC3. **Read** – A read is a data movement that moves a data group from persistent storage to within the functional process, which requires it. The movement is marked with “R”. For a visual example please view Table 25 in the appendix.

Modeling Rule COSMIC4. **Exit** – An exit is a data movement that moves a data group from a functional process across the software boundary to the user that requires it. The movement is marked with “X”. For a visual example please view Table 28 in the appendix.

The Figure 25 in the appendix provides the Order-to-Cash business scenario BPMN model with the applied COSMIC EPC method.

5.2.7. The COSMIC EPC and ARIS automation logic

This section provides a description of the automation opportunities applying the COSMIC EPC method to the ARIS EPC modeling toolset. The BPMN and COSMIC EPC rules defined earlier in this thesis can be used as the system logic for automation.

Concept Logic	**Automation**	**Rule description**
Function	Yes	Functional activity within a Business Process
Boundary	Yes	All the business processes within a certain Business scenario.
Swim Lane	Yes	Indicated line separating business processes within a business scenario.
Data Groups	Yes	Each information object that appears in the data model.

Entry	Yes	Each incoming event with an information object crossing a swim lane.
Entry	Yes	An input event which does not come from a function.
Exit	Yes	Each outgoing event with an information object crossing a swim lane.
Exit	Yes	Each outgoing event with an information object not used as input in the rest of the business scenario.
Read	Semi	An upstream association with an information object by a data read function.
Write	Semi	A downstream association with an information object by a data writes function.

Table 7: COSMIC EPC applied to ARIS EPC automation logic

The area of difficulty for automating the COSMIC EPC method into ARIS is the Read and Write data movements. A suggestion would be to first identify the Entry and Exit data movements and mark the remaining information objects with only one association connector. Those with the upstream association connectors should resemble (Write) data movement and those with a downstream association connector resemble a (Read) data movement.

5.2.8. COSMIC EPC consistency rules

The following consistency rules could be used to ensure a consistent Functional Point Size repository representing business scenarios with its related business processes. The following rules must be maintained for a coherent and consistent set of process scenarios. This could also be automated.

Rule Code	**Automation**	**Logical Rule description**
EPC1	Yes	The functional size of a business process represent by an EPC diagram is equal to the sum of all its related data movements
$Size(Business\ Process_i) = \sum(ENTRY_i) + \sum(EXIT_i) + \sum(READ_i) + \sum(WRITE_i)$		
EPC2	Yes	The functional size of a base business scenario is equal to the sum of its related business processes.
$Size(BusinessScenario) = \sum_{i=1}^{n} Size(Business\ Process_i)$		
EPC3	Yes	The functional size of a business process is equal to the sum of its extended process steps (sub processes).
$Size(Business\ Process) = \sum_{i=1}^{n} Size(Sub\_processes_i)$		
EPC4	Yes	The functional size of a software layer is equal to the sum of the functional sizes of its related business scenarios.
$Size(Layer) = \sum_{i=1}^{n} Size(Business\_Scenario_i)$		

Table 8: Scenario Process logic

5.2.9. COSMIC EPC Functional Size Measure

The following section provides a basic view of the COSMIC EPC model. This model presented in the excel format provide the logic and functionality integrated from the COSMIC EPC method. This model hosts the business scenarios with its related business processes and process steps. Table 29 in the appendix demonstrates the basic layout with Entry, Exit, Read, Write and Total Cfs score per business process. The data movements are counted on the lowest level of detail, on the process step level (Level3).

5.2.10. The COSMIC EPC model description

The following section describes the COSMIC EPC model (Figure 22 in the appendix) logic and use of this model in detail. In this section the COSMIC EPC model include several additional parameters such process customization (Modify tab) and reuse (Reuse tab). The process reuse and customization parameters will be explained in detail in its own section following.

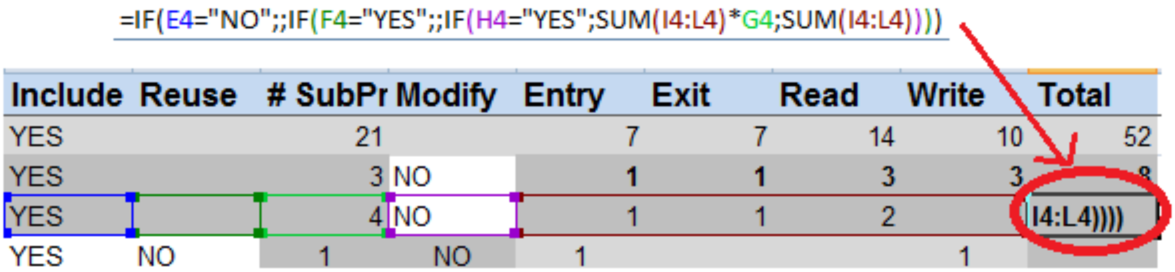
The "#Install" tab (column) represents the baseline (layer) or installation code of the business scenario and related functionality. This field is used to identify the installation codes for the ERP baseline for implementation purposes. The Business Process tab display the description or naming convention of the business scenario and its related business processes and process steps. The "Level" tab represent the process detail level which is either a business scenario (Level1), a business process (Level2) or a process step (Level3). The "Module" tab are not compulsory and only display to which ERP module the process belongs.

The "Include" tab is used to indicate whether to include the process step or not. If the "Include tab" is marked "YES" it resemble that the process step should be included. If the "Include tab" is marked "NO" it resemble that the process step should not be included. If the process step is not included it shows "0" under the tab "# SubPr" (sub processes) for that specific process step, otherwise if it is included it shows "1". Furthermore if the process step is not included, it changes the existing sizing model and reset the data movement digit to "0".

Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
1.2. Procurement Process	2	MM	YES		4	NO	1	1	2	1	5
1.1.1. Creating Purchasing Requisition	3	MM	YES	NO	1	NO	1			1	
1.1.2. Creating Purchasing Order	3	MM	YES	YES	1	NO				0	
1.1.3. Displaying Purchasing Order	3	MM	YES	NO	1	NO			1		
1.1.4. Display messages	3	MM	NO	NO	0	NO			0		
1.1.5. Display Processing Status	3	MM	YES	NO	1	NO		1	1		

Figure 7: The effect of the "Include" column

The process-step functional size total is calculated keeping certain criteria's into account. On the basic level the total functional size per business process is the sum of the data movements per business process. This is further influenced by the status of the related process reuse (Reuse) and customization (Modify) criteria.

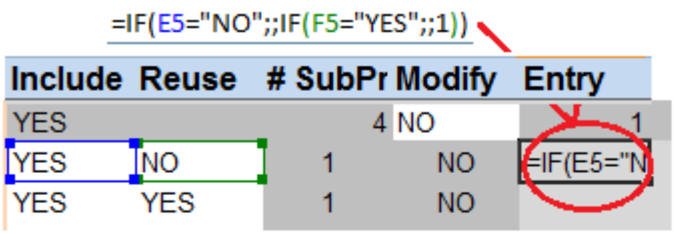

=IF(E4="NO";;IF(F4="YES";;IF(H4="YES";SUM(I4:L4)*G4;SUM(I4:L4))))

Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
YES		21		7	7	14	10	52
YES		3	NO	1	1	3	3	8
YES		4	NO	1	1	2		I4:L4))))
YES	NO	1	NO	1			1	

Figure 8: The total functional size per process step

5.2.11. COSMIC EPC - Size estimation and reuse

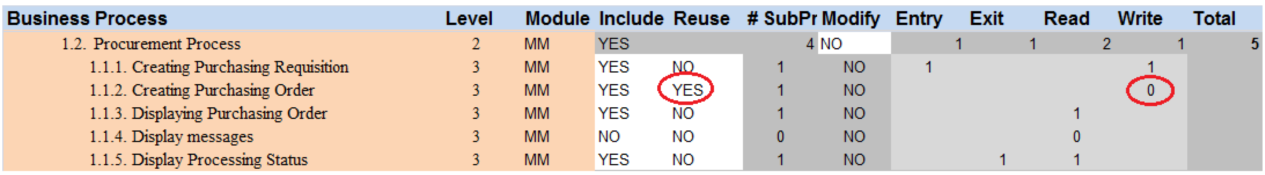
If the “Reuse” tab is selected “YES” it reset all the related data movement fields (Entry, Exit, Read, and Write) on the specific process step to “0” in that specific process step.


=IF(E5="NO";;IF(F5="YES";;1))

Include	Reuse	# SubPr	Modify	Entry
YES		4	NO	1
YES	NO	1	NO	=IF(E5="N
YES	YES	1	NO	

Figure 9: Formula for each data movement field

The logic of this is explained that if a process step is already been implemented or reserved by another business process, it does not require any more effort for implementation, therefore we exclude the size of these function points again. Process reuse always appears on the business process step (Level3- detail) level.



Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
1.2. Procurement Process	2	MM	YES		4	NO	1	1	2	1	5
1.1.1. Creating Purchasing Requisition	3	MM	YES	NO	1	NO	1			1	
1.1.2. Creating Purchasing Order	3	MM	YES	YES	1	NO				0	
1.1.3. Displaying Purchasing Order	3	MM	YES	NO	1	NO			1		
1.1.4. Display messages	3	MM	NO	NO	0	NO			0		
1.1.5. Display Processing Status	3	MM	YES	NO	1	NO		1	1		

Figure 10: Reuse of the process step.

To determine the overall amount of reuse per business process would already reflect in the functional size per business process (Level2). In case the RE or PM still like to report specifically on the overall amount of reuse and percentage of reuse, Daneva [54] provided the following formulas.

Overall amount of reuse = Amount of reused associated with process

The percentage of reuse in the software is derived as follows:

$$Percentage.of.reuse = \frac{Overal.amount.of.reuse}{Size.of.software.measured.without.reuse} x100$$

5.2.12. COMIC EPC - Size estimation and modification

If the ”Modify tab” is selected ”YES” it affects the complete business process. The logic behind this is that if one process-step is modified (customized) it affects the other process steps related to the business process. Therefore a “YES” for a single process-step will change the business process “Modify” status to “YES”. Process customization always appears on the business process (Level2- detail).

Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
1.1. Customer Master Data	2		YES		3	YES	1	1	1	2	15
1.1.1. Create Customer	3	SD	YES	NO		YES	1			1	
1.1.2. Extend Customer master data	3	SD	YES	NO		NO				1	
1.1.3. Display Customer master Record	3	SD	YES	NO		NO		1	1		

Figure 11: Modification of a process step.

The number of the total sub processes (representing the process steps level 3 -detail) are displayed on the business process (level 2 –detail) as displayed in Figure 12.

# SubPr	Modify	Entry	Exit	Read	Write	Total
3	YES	1	1	1	2	15
	YES	1			1	
	NO				1	
	NO		1	1		

Figure 12: Sub process count related to a Business Process

The business process total functional size count is affected by the modification caused by the business steps. If the Modify field is selected and marked “YES” by any one of the process steps, modification will influence the whole business process. The sum of the data movements for the business process is multiplied by the amount of process steps active (Included) in the business processes.

In the example below the Cfs is 5 functional size points multiplied by 3 process step. Therefore the functional size is now 15 Cfs taking (Modify) customization into account.

Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
YES		3	YES	1	1	1	2	15
YES	NO		YES	1			1	
YES	NO		NO				1	
YES	NO		NO		1	1		

Figure 13: The effect of a modification on the Cfu total

5.2.13. The SAP ASAP - COSMIC EPC prototype

This section introduces the COSMIC EPC model integration into the SAP ASAP Solution Manager. The SAP ASAP Solution Manager would then be used to provide an overview and the estimates for the ERP implementation by providing an overall size for the project. The scenario structure and integration opportunity using a COSMIC EPC method for sizing an ARIS EPC model and the synchronization of the result into the SAP ASAP Solution Manager tool. Currently the ASAP solution manager contain three levels that can be used to integrate the COSMIC EPC model as displayed in Figure 21 in the appendix.

1. The business scenario (e.g., order-to-cash) which represent Level1 detail.
2. The business processes for each scenario (e.g., domestic sales) Level2 detail.
3. The business-process step (e.g., entering the sales orders) Level3 detail.

This section displays an example of the Order-To-Cash business scenario as a COSMIC EPC model and provides an industry contribution by suggesting a newly developed prototype (add-on functionality) and integration of a newly packaged COSMIC EPC method within the existing SAP ASAP Solution Manager.

Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
Order to cash process overview	1		YES		18		7	6	5	11	**51**
1.1. Customer Master Data	2		YES		3	YES	1	1	1	2	**15**
1.2. Sales conditions	2		YES		2	NO	0	0		0	**0**
1.3. Sales Order Management	2		YES		1	NO	0	0		0	**0**
1.4. Material requirements Planning	2		NO		0	NO	1	1	1	2	**0**
1.5. Producing Item	2		YES		4	NO	1	1		2	**4**
1.6. Shipping Processing	2		YES		4	YES	1	1	1	2	**20**
1.7. Billing	2		YES		1	YES	1	0	0	1	**2**
1.7.1. Create Billing document	3	SD	YES	NO		YES	1			1	
1.7.2. Display document flow	3	SD	NO	NO		NO		1	1		
1.8. Incoming Payment	2		YES		1	NO	1	1	1	1	**4**
1.9. Reporting	2		YES		2	NO	1	1	1	1	**4**

Figure 14: Order-to-Cash example of the COSMIC EPC method version 2

The ASAP screenshot (Figure 23 in the appendix) represent the contributed prototype (add-on functionality) which demonstrates the integration of the new COSMIC EPC method within the SAP ASAP Solution Manager environment. The logic used for the prototype is directly derived from the described COSMIC EPC model above. Therefore by integrating the COSMIC EPC method best fitted into SAP's current ASAP environment we can reduce the amount of effort to deliver estimations (through automation logic) and increase the accuracy to estimate project effort.

5.2.14. The SAP ASAP Project Repository

Each business scenario is usually provided in the ARIS model format by the ERP vendor. The COSMIC EPC method applied to the ARIS EPC tool could provide a Cfs for each one of these template scenarios. A template business scenario represents the standard functionality without process reuse or customization. This business scenario model is created to be as generic as possible to be used by most industries. A project repository (ASAP) could contain these template scenarios with an estimated time for implementation (carried out by a SAP level 3 implementation engineer) and the total Cfs (COSMIC function size) per business scenario. In the following example Table 9 you will see the template data for the Order-to-

Cash scenario. The Order-to-Cash template data will be used in the time estimation calculation in the following section.

Order-to-Cash (ST) Scenario Template	
Time to implement	18 hours
Total functional size	24 Cfs

Table 9: Order-to-Cash scenario template

5.2.15. COSMIC EPC Time and Cost estimation

This section demonstrate how the time and cost estimations can be calculated using the Cfs and COSMIC EPC model. The calculation used the Order-to-Cash scenario template (Table 9) and the project data used in the COSMIC EPC prototype demonstration in chapter 5.2.13 displayed in more detail in (Figure 24 in the appendix).

From the Figure 24 in the appendix we can conclude that in this example the projects Order-to-Cash scenario has: 51 Cfs (COSMIC functional size) points, 3 reuse (business process steps - Level3 detail) and 3 customization (Business processes - Level2 detail) processes.

Order-to-Cash Example project	
Functional Size	51 Cfs
Reuse	3
Modify	3

Table 10: Order-to-Cash sample summary

To move to the next step, the cost per hour is needed. Usually a SAP consultant or implementation engineer is ranked from Level1 to Level5, depending on their experience. The rule of thumb is that if there are a high number of customizations we would like to use a higher level consultant as complexity increase. This key figure usually represents the overhead cost charged to the client. The conversion factor is used for the time calculations and the Unit costs for the cost estimates.

Standard Unit Cost (SUC) for implementation Engineer					
Level	Level1	Level2	Level3	Level4	Level5
Unit cost (Euros) p/hour	550	1100	1350	1750	2500
Conversion factor	1,6	1,1	0,9	0,75	0,6

Table 11: Standard Unit Cost

The following steps demonstrate how the COSMIC EPC method could be used to calculate time and cost effort estimates.

Step1: Calculate the Time

The key figures used in the time calculation could be found in Table 9 which present the scenario template (Scenario Template Time - 18), Table 10 presenting the example project data (Project Cfs - 51) and Table 11 containing the unit overhead costs and conversion rate per engineer level (Conversion factor – 0,9) above.

Formula:

$$SI\_Time = ST\_Time \times SUC\_Conversion\_factor \times (Cfs / ST\_fs)$$

SI (Scenario Implementation) Time
ST (Scenario Template) Time
SUC (Standard Unit Cost) Conversion factor
Cfs (COSMIC functional size) of the project data
ST fs (Scenario Template functional size)

Calculation:
SI Time = (18 x 0,9 x (51/24))
SI Time = 35

The SI Time indicates that the business scenario (Order-to-Cash) implementation for this project is estimated to take 35 hours.

Step2: Calculate the Cost

In the following step we only require the scenario implementation time calculated above (35 hours) and the unit overhead cost related to the implementation engineer level displayed in Table 11.

Formula:

$$SI\_Cost = ST\_Time \times SUC\_Unit\_Cost$$

SI (Scenario Implementation) Cost
SI (Scenario Implementation) Time
SUC (Standard Unit Cost) Unit Cost

Calculation:
SI Cost = 35 x 1350
SI Cost = 47250

The SI Cost indicates that the business scenario (Order-to-Cash) implementation for this project is estimated to cost 47250 Euros.

Step3: Add up the total Time and Costs

In this example we only presented how one business scenario can be used to calculate estimations for cost and time. In practice the estimator or PM has to repeat the same process for all business scenarios and add up the total time and cost for the complete project. This could be automated using the ASAP prototype. The Time and Cost example scenario estimation results are presented in Table 12 below.

Scenario Implementation Estimations	
Time (hours)	35

Cost (Euro)	47250

Table 12: Example scenario implementation estimate

6. Evaluation

This chapter provides the evaluation of the COSMIC EPC method and the supportive tools as ad-on functionality for the ASAP and ARIS EPC applications. The evaluation will be conducted with both a qualitative and quantitative approach.

6.1.The research interviews as evaluation

The first evaluation is done with a qualitative approach using the SAP follow-up interviews and external consultant interviews to evaluate the COSMIC EPC method and supportive toolsets. The interviewees provided feedback of the method and tools based on the criteria displayed from point 1 to 7 below. The criteria were derived from the SAP observations and the SAP semi-structured interviews with the PM and RE experts.

The criteria derived during the first evaluation round were transformed into questions. In the questions where method or tool are mentioned, the evaluation was done separately for the method and each individual tool; where method represent the COSMIC EPC method, tools represent the ARIS EPC tool and ASAP Solution manager tool. The following questions were used to evaluate the method and supportive tools:
1. How accurate is the functional size estimates using the FSM method or tools?
2. What effect does BP (Business Process) reuse have on effort estimates?
3. What effect does BP customization have on effort estimates?
4. Does the method and tools incorporate cross module complexity of an ERP implementation project?
5. Does it contribute to reduce the estimation complexity for the estimator?
6. Does it contribute to the need to reduce cost?
7. Does it require a higher level of estimation skill?

6.1.1. Evaluation of the COSMIC EPC method

The interviewees had the opportunity to participate in a demonstration of the COSMIC EPC method. The following scorecard is used to evaluate the method based on the questions and criteria's recorded during the interviews.

	SAP Walldorf	SAP St.Gallen	SAP Zurich	SAP London	SAP Den Bosch	SAP Goteborg	Logica Baden	KPN Gravenhage	Accenture Amsterdam	Accenture Zurich	IBM Stockholm	D1 Solution
COSMIC EPC Method												
1. The COSMIC EPC method accurateness	√√	√√	√√	√	√√	√√	√√	√√√	√	√√	√√	√√
2. Effect of BP reuse	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√
3. Effect of BP customization	√√√	√√√	√√√	√√√	√√	√√√	√√	√√	√√	√√	√√√	√√
4.Incorporate cross module complexity	√√	√√	√√√	√√√	√√√	√√	√√	√	√	√√	√√	√
5.Reduce estimation complexity	√	X	X	X	X	X	X	X	X	X	X	√
6.Reduce cost	√√	√	√	√	√	√	X	√	X	X	√	X

7.Reduce estimation skill required	X	X	X	X	X	X	X	X	X	X	X	X

X-does not support / √ - participate / √√ - make a good impact / √√√ - extraordinary contribution

Table 13: The COSMIC EPC evaluation table

Table 31 in the appendix describe the level of agreement by the interviewees used in the scorecards.

The evaluation in Table 13 (of the COSMIC EPC method) provides the following conclusions: 10 out of 12 users (interviewees) of the COSMIC EPC method strongly agreed that the method should provide accurate estimations in their opinion. Other areas of strong agreement include the incorporation of process reuse (12 users) and exceptionally strong agreement (12 users) for taking customization into account. They mentioned that this has not been considered with previous estimation methods. Furthermore 8 users provide a high score for taking the ERP cross module complexity into account by measuring on a process step (Level3) level. The negatives communicated by the users was that the COSMIC EPC method increase estimation complexity (8 users), increasing cost doing the estimates (3 users) and need a higher level of estimation skill to perform the estimations (12 users).

6.1.2. Evaluation of the ARIS EPC tool

The interviewees had the opportunity to participate in a demonstration of the ARIS EPC support tool which is used to identify the functional points using BP models as input. The following scorecard was used to evaluate the tool based on the feedback gathered during the SAP follow-up and external consultant interviews.

	SAP Walldorf	SAP St.Gallen	SAP Zurich	SAP London	SAP Den Bosch	SAP Goteborg	Logica Baden	KPN Gravenhage	Accenture Amsterdam	Accenture Zurich	IBM Stockholm	D1 Solution
ARIS EPC – COSMIC EPC integration												
1. The ARIS EPC tool accurateness	√√√	√√√	√√√	√√	√√√	√√√	√√√	√√√	√√	√√√	√√	√√√
2. Effect of BP reuse	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√	√√
3. Effect of BP customization	√√√	√√√	√√√	√√√	√√	√√√	√√	√√	√√	√√	√√√	√√
4.Incorporate cross module complexity	√√	√√	√√	√√√	√√	√√	√√	√√	√√	√√	√√	√
5.Reduce estimation complexity	√√	√√	√√	√	√√	√	√√	√√	√√	√	√	√√
6.Reduce cost	√√√	√√√	√√√	√√√	√√√	√√√	√√	√√	√√√	√√√	√√√	√√
7.Reduce estimation skill required	√√√	√√	√√√	√√√	√√	√√	√√	√√	√√√	√√√	√√√	√√

X-does not support / √ - participate / √√ - make a good impact / √√√ - extraordinary contribution

Table 14: The ARIS EPC evaluation table

The evaluation in Table 14 (where the COSMIC EPC method was applied into the ARIS EPC tool) the following conclusions are made: The interviewees (12 users) provide a strong agreement for estimation accurateness. Their motivation was related to the process followed to generate the Cfs per process step (lowest level of detail) which in their opinion will increase the accuracy. Consideration of process reuse and customization also received a high score with the only difference is that the COSMIC EPC method data movement counts could be atomized. All the users expressed their opinion that automating processes will make a tremendous impact to reduce the estimation complexity, while reducing the skill needed to estimate and intern reduce the cost associated to perform this estimates.

6.1.3. Evaluation of the ASAP EPC tool

The interviewees had the opportunity to participate in a demonstration of the ASAP support tool which has been used for ERP project management and function point estimation counts as an input for effort estimation. The following scorecard was used to evaluate the tool based on the feedback gathered during interviews.

	SAP Walldorf	SAP St.Gallen	SAP Zurich	SAP London	SAP Den Bosch	SAP Goteborg	Logica Baden	KPN Gravenhage	Accenture Amsterdam	Accenture Zurich	IBM Stockholm	D1 Solution
ASAP – COSMIC EPC integration												
1. The ASAP tool accurateness	√√	√√	√	√	√	√	√	√√	√√	√√	√√	√√
2. Effect of BP reuse	√√√	√√	√√√	√√√	√√	√√√	√√	√√	√√	√√	√√	√√
3. Effect of BP customization	√√√	√√√	√√√	√√√	√√	√√√	√√	√√	√√	√√	√√√	√√
4.Incorporate cross module complexity	√√√	√√	√√	√√√	√√	√√√	√√	√	√√	√√	√√√	√
5.Reduce estimation complexity	√√√	√√√	√√√	√√√	√√√	√√√	√√	√	√	√	√	√√
6.Reduce cost	√	√	√	X	√√	X	X	X	X	X	√	X
7.Reduce estimation skill required	√√√	√√	√√√	√√√	√√	√√	√√	√√	√√√	√√√	√√√	√√

X-does not support / √ - participate / √√ - make a good impact / √√√ - extraordinary contribution

Table 15: The ASAP evaluation table

The evaluation in Table 15 (where the COSMIC EPC method was applied into the ASAP solution manger tool) the following conclusions are made: The SAP ASAP tool provides an interface for project management with the sufficient amount of detail to have an overall picture of the ERP project. The requirements engineers (5 users) provide feedback that the tool might reduce the accuracy of estimations but at the cost to make the tool useful and less complicated for project management. Overall both user communities agreed (all users) that the tool makes an enormous impact to fit into the current practices, maintaining a high level of accurateness, reducing estimation complexity and reducing the skill needed to provide the estimation. They mentioned that the ASAP COSMIC integration might increase the cost of estimation as a start (7 users), but in their opinion is a small price to pay for accurate effort estimates.

6.1.4. Additional Interview feedback

The following section provides a elaborative list of additional feedback and interpretations noted during the interviewees concerning the COSMIC EPC method and its related ARIS and ASAP tool:

1. Three interviewees were concerned about the varying qualities of the functional point estimates delivered by different individuals. A SAP PM employee at Walldorf mentioned “the success of this method highly depends on the skill of the individuals using the COSMIC EPC method”. A SAP employee participating as a RE provides feedback on this question by saying “If the process is systematically documented with clear instructions it will reduce the amount of varied qualities provided by different estimators.”

2. Two interviewees mentioned that business scenarios could contain repetitive business processes and mentioned that these should not be counted more than once during FSM. The logic behind this is that a certain ERP module or functionality only need to be configured once and can be reused by several modules. This support the COSMIC EPC method which considers the reuse of a specific BP function points only once and do not recount the same business process in another module within the same project .

3. The effect of customization on an ERP project is enormous according to four of the interviewees. One PM employee at SAP Zurich said that: “The current estimation methods do not account for customization, how will the COSMIC EPC method be any different and increase the estimation accurateness?” Four RE feedback interpretations answer this by explaining that the predefined modules (scenario templates commonly used by estimators) with fixed time estimations do not consider process customization and provide inaccurate effort estimation results. They also made a remark that the COSMIC EPC method according to them does compensate for process customization on a level of detail, low enough (on a business process level) to justify the customization in the form of Cfs (Cosmic functional size) points. According to them the business process level is the level that will affect customization effort most.

4. The interviewees mentioned that following a FSM method itself could increase project management complexity. In the case of the COSMIC EPC method it does require more effort during project planning, the effort required to execute the COSMIC EPC method could be reduced significantly with the recommended ASAP and ARIS EPC supportive tools.

5. The interviewees mentioned that changing from a current effort estimation method to a FSM method might incur an enormous amount of costs to recount all the BP models. In the case of the COSMIC EPC method it is true that such a change will endure great costs. However with the supportive toolsets it’s possible to reduce the manual activities of measuring each BP and could automate the function point identification with the ARIS EPC add-on functionality. Once a BP is measured by the COSMIC EPC method it could be stored and be reused in other SAP ERP project effort estimations. Therefore there will be a high once-off cost with the introduction of the method and a lower continuous cost for accurate effort estimates.

6. The interviewees mentioned that the COSMIC EPC method require a certain level of skill which might be difficult to find. The COSMIC EPC method is manageable through the supportive toolset which is created for a lower level of skill, where the manual process of using the COMIC method (without tool support) requires an increased level of skill.

6.2.Project data as evaluation

The quantitative evaluation is carried out using 9 SAP ERP projects to evaluate how accurate the suggested and existing FSM method is at SAP. The evaluation includes both the original method (Expert Judgment) used by SAP currently, but also evaluate how the new method (COSMIC EPC) perform in delivering time and cost estimates of the 9 SAP project data.

6.2.1. Evaluation of the Expert Judgment method

In this study we only focus on the evaluation of the Cash to Order scenario as a subproject, for comparative flexibility. The following quantitative evaluation was carried out to evaluate the expert judgment method with the 9 SAP ERP projects.

Project	1	2	3	4	5	6	7	8	9
Expert Judgment Cash to Order									
Time	16 hrs	16 hrs	21 hrs	16 hrs	16 hrs	24 hrs	16 hrs	24 hrs	16 hrs
Cost	21600	17600	23100	40000	21600	26400	21600	13200	21600
Actual resources used									
Time	20 hrs	24 hrs	29 hrs	10 hrs	22 hrs	23 hrs	41 hrs	59 hrs	28 hrs
Cost	27000	26400	31900	25000	29700	25300	55350	32450	37800

Table 16: Expert Judgment estimation results

This evaluation includes measuring the estimates of the previous effort estimation method namely the “expert judgment” method and comparing these estimates with the actual resources used. The values which were evaluated and compared include the time and cost factors.

6.2.2. Evaluation of the COSMIC EPC method

The quantitative evaluation was carried out to evaluate the COSMIC EPC method with the 9 SAP ERP projects. In this evaluation we use the COSMIC EPC method with the same data which is available during the pre implementation phase of an ERP project. We used the formulas to calculate the Time and Cost estimates as presented in chapter 5.2.15. The project data used for the calculations are the same data used in the evaluations for the expert judgment method above. The conversion and unit cost data used to calculate the result below could be found in the appendix Table 30.

Project	1	2	3	4	5	6	7	8	9
COSMIC EPC method Cash to Order									
Time	18 hrs	26 hrs	32 hrs	9 hrs	23 hrs	22 hrs	48 hrs	62 hrs	26 hrs
Cost	23692	29040	35392	23625	30982	24502	64698	34320	34627
Actual resources used									
Time	20 hrs	24 hrs	29 hrs	10 hrs	22 hrs	23 hrs	41 hrs	59 hrs	28 hrs
Cost	27000	26400	31900	25000	29700	25300	55350	32450	37800

Table 17: COSMIC EPC Project Data

6.2.3. Comparing COSMIC EPC with Expert Judgment

The following table presents a comparison between the SAP`s existing effort estimation method using expert judgment versus the COSMIC EPC method.

The Expert judgment method shows that 7 out of 9 projects (77%) were over time, where the estimates present an average of 39% over the actual time. The COSMIC EPC method show that 4 out of 9 projects (44%) were over time, where the estimates were by average only 8% over the estimated time. Therefore with a 10% buffer none of the COSMIC EPC project estimates would be overtime. The average overtime percentage is calculated by selecting only the estimates which time value went over the actual time figure (marked in red) and add up the percentages divided by the number of projects that is over the actual time for that specific method. There is no need to calculate the cost as the formula use the time as the variable and cost unit as a constant therefore this will show the same statistical results as for the time factor. Table 18 demonstrates the comparative figures per project for the COSMIC EPC and Expert Judgment method.

Project		**COSMIC EPC**		**Expert Judgment**	
	Actual Time	**Estimated Time**	**% over time**	**Estimated Time**	**% over time**
Project1	20	18	10%	16	20%
Project2	24	26	-8%	16	33%
Project3	29	32	-10%	21	28%
Project4	10	9	10%	16	-60%
Project5	22	23	-5%	16	27%
Project6	23	22	4%	24	-4%
Project7	41	48	-17%	16	61%
Project8	59	62	-5%	24	59%
Project9	28	26	7%	16	43%
Average Overtime			**8%**		**39%**

Table 18: Comparison of COSMIC EPC and Expert Judgment method

In conclusion the COSMIC EPC method shows to be more accurate than the existing Expert Judgment method.

The evaluation of the relationship between COSMIC EPC parameters: functional size, time, cost, process reuse and customization are described in detail in the appendix Chapter 11.4.

7. Discussion

This thesis makes contributions to the field of SEM and the ERP industry in several ways. Unlike research before (Monsalve C. A., IWSM/MetriKon/Mensura '10: International Conferences on Software Process and Product Measurement, Stuttgart, G, 2010) (Monsalve C. , Measuring software functional size from bussiness process models), we apply and adapt a FSM method specifically for the ERP domain. In most studies which provide a method used in a example in the industry, the author/s demonstrate the use of a FSM method on a technology driven application like “embedded systems” (which is proven to be different than the business application domain), which do not make it clear how to implement such a method in the ERP domain. This thesis also contributes to FSM methods by providing a new COSMIC EPC method designed for large scale and complex enterprise systems, specifically designed for SAP ERP projects. Due to the similar characteristics that most ERP systems present (by using BP as the baseline attribute to describe their functionality), the COSMIC EPC method could be used by most major ERP vendors which shown in the impact chapter of covering at least 74% of the industry.

This thesis provides to the science of FSM methods the first set of SAP ERP project data that was being used for testing the COSMIC method. Most of the previous studies like (Vogelezang, 2006) analyze the COSMIC method on interface (level1) which does not demonstrate how to make use of business scenarios and business processes with their related process steps. We believe unless an author has actually tried a method and applying it in a real case, the theory or suggested method would not hold and distant itself from the real problems in its targeted domain. Therefore this thesis place emphasis on the industry needs and concerns by including several leading organizations in this domain as part of the formulation process of developing the thesis concepts by using the action research method.

This thesis also delivers a toolset as add-on functionality within the existing SAP ASAP Solution management application, which is widely used by the ERP vendors and adapters for SAP ERP implementation project management. The toolset also include an upgrade (add-on-functionality) for the existing ARIS EPC tool (Scheer A. W., 2000). This enhances the synergies developed between the requirements engineer (which contain knowledge about the problem domain “As-is” and the required business processes “To-be”) and project management (which contain knowledge about the ERP team, time and budget constrains) to improve their estimation capabilities and synergies together. The RE in the ERP domain is often an individual with experience, training and education within BPM (Business Process Management) or specialized industry certification such as the SAP TERP10 while providing certain soft skills for facilitation of meetings representing several stakeholders. The RE engineer provides important information and input for effort estimation while the PM role used this information as input to influence and estimate the total time and budget constraints. The PM still need the RE beyond providing the FSM inputs as the RE understand the consequences of certain demands such as process customization and making best use of process reuse which could be communicated in Cfs units while the PM communicate the effect of this in terms of time and budget constraints.

The ERP pre-implementation phase which balance negotiation and requirements elicitation with the client may include several discussions to determine the best option to satisfy the client (stakeholder/s that the request and sponsor the ERP implementation) needs while acting in the best interest of this client. Several authors in the SE domain separate the task of effort estimation as a task only belonging to the PM role which explains the very root of the problem itself. For example the actual solution or method is often misaligned with the ERP practice today. In this thesis we emphasize the overlapping role of effort estimation as a shared task between the RE and the PM and confirmed this in the thesis by observing two ERP pre-implementation projects and supporting contributions derived during the interviews. Failure to convert the information derived from the RE as input to effort estimation will either witness continuous ERP project failures or even witness the increase of ERP project failures to come, as ERP implementations increase in complexity aligned with more complex business structures and strategies executed through their business processes. For many organizations to survive, they need to innovate their business processes and often make it more complex for the following reasons (Davenport T. , 1993); to react on rising competition and deliver a unique business model or to increase complexity intentionally to reduce the changes of competitors copying their process innovation and sell it internally as the core competence and dynamic capabilities. In this thesis we strongly communicate the message that successful ERP implementations originate from accurate effort estimates with strong communication and knowledge transfers between the RE and PM.

The ARIS EPC tool is currently used to design and communicate the desired business processes. This tool can now be upgraded with the add-on-functionality to convert the business scenarios with their underlined processes into functional sizes, by using the COSMIC EPC method created in this thesis and demonstrated in practical terms. The SAP project manager can use the ASAP Solution manager add-on-functionality for the functional size conversions for level1 (business scenarios), level2 (business processes) and level3 details (described as the related process steps). The lower the level of detail (where level1 is the highest and level3 the lowest level of detail) the more accurate the estimation will be, but consequently increase the required effort and skill to deliver the estimation which is a undesired situation as documented during the thesis interviews, both within SAP and representing external (SAP adaptors) consultancy firms such as Accenture, IBM, Logica, KPN and D1 solutions across Europe. The challenge in this thesis was to increase the level of detail in the effort estimation process while minimizing the effort and skill required for incorporating level3 detail (Process steps) within the effort estimates.

The COSMIC EPC method provide a counting model which forms the basis concept functionality for the ASAP solution which was presented in this thesis as a excel spreadsheet. This thesis addresses several problems, which were presented as high level theoretical and concept suggestions formulated in previous research (Vogelezang, 2006) (Daneva, Complementing Approaches in ERP Effort Estimation Practice: an Industrial Study., PROMISE '08 Proceedings of the 4th international workshop on Predictor models in software engineering, 2008) (Daneva, An assessment of the effects of requirements reuse measurements on the ERP requirements Engineering process, 2006) (Monsalve C. A., IWSM/MetriKon/Mensura '10: International Conferences on Software Process and Product Measurement, Stuttgart, G, 2010) (Monsalve C. , Measuring software functional size from bussiness process models) (Daneva, Establishing Reuse Measurement Practices in SAP Requirements Engineering, 2000) (Daneva, ERP Requirements Engineering Practice: Lessons Learnt, IEEE Software, 21(2), 2004) (Daneva, Evaluating the Value-added Benefits of Using Requirements Reuse Metrics in ERP Project, 2001) (Daneva, Preliminary Results in a Multi-site Empirical Study on Cross-organizational ERP Size and Effort Estimation, 2008) and combine it into a single method with a supportive toolset to address the industry concerns.

A major problem with relating an existing FSM method to the ERP domain avoids BP reuses and process customization all together, which seems to be a major factor in ERP effort estimation. The effect that BP reuse (Daneva, Reuse Measurement in the ERP Requirements

Engineering Process, 2000) and customization have on a project could be explained as taking account for the complexity of ERP implementations within a certain environment which ultimately affects the accurateness of the estimation. The relationship between BP reuse, BP customization and functional size was also explored in this thesis within the evaluation chapter. Even though the founding's might be based on a small sample (9 ERP projects) it delivers a new understanding of the affect that these factors yield when combined in a project. Understanding these parameters better will affect the accurateness of ERP effort estimations and allow the industry with the possibility to create tools to capture, analyze and calculate the impact of these parameters within ERP effort estimation. This thesis delivered a formula to convert the functional size of business scenarios with their related business process into cost and time estimate. Future research might be able to use the COSMIC EPC method with large scale business application estimates outside the domain of enterprise systems.

8. Conclusion

This thesis investigates the use of FSM (functional size measurement) as an early input for effort estimations of ERP implementations. Early size estimates are useful to manage client expectations. Some of the clients of the ERP implementations do not have a good understanding of the impact of their business processes. For these clients the size estimates are an effective tool as input towards accurate time and cost estimates [4].

The main reason for choosing the COSMIC method as a basis for FSM is based on the kind of documentation that is usually available at the start of an ERP pre-implementation phase. When only process information is available, the COSMIC EPC method has an advantage over other sizing metrics and function point estimation models. This experience shows that Cfs (COSMIC functional size) can be used as the basis of the estimation of ERP implementations that requires customization of BP (business processes) determined by the RE (requirements engineer) during the pre-implementation phase. In this thesis we emphasize the important role of the RE as part of the effort estimation process. The customization of BP is an important input that cause a drastic explosion of effort in terms of time and cost, while process reuse reduce the amount of effort required for ERP implementations. Until now there is no standard way to measure the impact of these process customizations or processes reused within an ERP implementation project.

This thesis delivered a new FSM method named the COSMIC EPC. Add-on functionality is provided for the ARIS EPC tool which makes use of BP models as input. The thesis provides a COSMIC EPC model applied to the SAP ASAP Solution manager for managing the reuse and customization of business processes during functional size estimations. The thesis provides evidence that the Cfs (COSMIC functional size) has a positive correlation to both cost and time parameters. A bigger Cfs often suggests a higher costs or longer project duration. Customization of the BP has a large exponential and positive impact on both cost and time, while the reuse of BP steps has a moderate negative impact on both the cost and time factors. It was clear that the reuse and customization of BP needs to be integrated into the current effort estimation practices.

The thesis indicates that 77% of the effort estimates using the existing "expert judgment" method was running over the actual project time by an average of 39%. The COSMIC EPC method had no projects running over the actual time (within a 10% buffer) and those that did run over the time within the buffer was only running over the actual time by an average of

8%. By using the COSMIC EPC method a PM and RE can reduce project failures and increase successful, reliable and accurate effort estimations for ERP implementations.

We conclude that when adding new parameters to the estimation methods the sizing of ERP projects can effectively be improved. The parameters include reuse and customization of business processes steps which increase visibility and understanding of the complexity and finally increase the accuracy involved in ERP effort estimations. The COSMIC EPC method can be used to produce accurate time and cost estimates and improve on the existing expert judgment methods used today.

Future research can include using and testing the COSMIC EPC method with a larger sample and other ERP vendors. The ERP in a cloud is a new and strategic topic for bigger (Tier1) ERP vendors. The COSMIC EPC method might also be used and tailored for the ERP in a cloud solution for cost, time and effort calculations.

9. Impact

The dynamics of the SAP ERP brand is representative of the ERP industry itself and also relatable to the characteristics of other major ERP brands in the industry. Some of the larger (Tier I) ERP vendors, like SAP, Baan, Sage and Oracle structures business content in a logical views using business scenarios and business processes. SAP's ASAP is similar to Baan's Dynamic Enterprise Modeling, Sage`s ERP X3 and Oracle's Fast-forward applications for ERP implementation management of business process integration [55]. Similar to the SAP ARIS EPC tool, Oracle present the Business Process Analysis Suite which could also be modified for integrating the COSMIC EPC method and add-on functionality. Taking the ERP market segmentation Figure 31 [56] into account we could reason that the COSMIC EPC method could have an impact on at least 74% of the ERP industry today.

Further analysis indicates that 80% of all ERP implementations exceed time and budget estimates reported by Gartner [57], similar to the findings of the Expert Judgment method used in this thesis. The majority of the reasons why ERP projects run over budget were reported in by Panorama research (displayed in Figure 39 in the appendix) as: consulting fees under estimations 14%, unanticipated technical complexity 19% and expanded project scope 32% [58]. The COSMIC EPC method could reduce as much as 65% of these project budget overruns. Panorama research (Figure 37 and Figure 38 available in the appendix) suggest that 4.4% of projects are completely customized, 19.4% heavily customized and 47.8% partly customized [59]. Therefore 71.6 % of ERP projects will be affected by customization which currently are not properly accounted for during effort estimations and could be accounted for using the COSMIC EPC method.

Legal law suits between ERP vendors and their clients have cost several millions of Euros and huge brand damages in the last 10 years. In this thesis we investigate at least 5 law suits which could be avoided by making use of effort estimation methods that could predict more accurate time and cost estimations. The case examples are available in the appendix chapter 11.12.

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11. Appendix

Keywords	ERP effort estimation
	ERP price estimates
	ERP Cost estimates
	ERP project management
	ERP pre - implementation
	ERP requirements engineering
	ERP project failure
	ERP project best practices
	ERP implementation success factors
	FSM (Functional Size Estimation)
	BP (Business Processes)
	BP integration
	BP models as input for requirements
	ERP reuse
	ERP adopters/ Vendors
Domain	SAP effort estimation
	SAP project management
Methods	FSM methods
	COSMIC FSM / FSS

Figure 15 Literature review keywords list

11.1. Interview Questions

11.1.1. SAP AG semi-structured interview questions

The following questions were used during the primary data collection phases described in chapter 2.2.1 with the project managers and requirements engineers during the observations (step 1) and SAP interviews (step 2): .

Q1.1: How do you or your department estimate the effort of an ERP implementation during the early phase of project planning?

Q1.2: What tools (software) do you use?

Q1.3: At what level of granularity do you measure the project size, time and overall cost?

Q1.4: Out of your experience, what is the best practice/s to provide an accurate estimate for ERP implementation?

Q1.5: In certain cases studies it has been mentioned that SAP ERP Implementation use a certain Project Management toolset. Which of the following do you use?
A – SAP ASAP

B – SAP Provided Excel spreadsheet
C – Own spreadsheet
D – Other approach … please explain.

Q1.6: How do you or your department account for the time, size of the project and cost of an ERP implementation and how does this affect the estimations.

Q1.7: In your opinion, is the method you're using effective in general? Please provide why you say it is or are not effective.

Q1.8: Do you or your department include reuse and modification as part of the effort estimation practice. Please provide a detailed description or explanation.

Q1.9: Would you be able to demonstrate through an example how you estimate the effort in terms of time, cost and size of an ERP project within the pre-implementation phase of a project? Please describe which stakeholders are involved and what activities they perform in the RE phase.

Q1.10: In your professional opinion, could you elaborate on the topic of Functional Point Estimation (after the introduction of FSM to the interviewee) and the potential role this could play for ERP project estimation?

11.1.2. Method validation (Follow-up) interview questions

The following themes were used as a guide during the primary data collection phases described in chapter 2.2.1 (step 3) SAP follow-up interviews and (step 4) external consultant interviews:

Theme opening statement: Looking at the COSMIC EPC method and model (excel spreadsheet) which we provide to you in this interview, could you see a potential of this method to improve your current practices? Please elaborate on the topic of the use and fit of the COSMIC EPC method in your practice.

Second theme discussion: Looking at the suggested COSMIC EPC method integrated into the ASAP and ARIS EPC solution, could you see opportunity for significant improvements? Please explain and elaborate on the potential strengths, weaknesses and potential improvements on functional level (referring to the add functionality of the ARIS and ASAP toolset).

11.2. Threats of validity categories [28]

History: Some interview participants may give an answer that does not truly reflect the real practices, but rather the way they think it should work. In the first situation we aim to specifically ask the interviewee to express only the current practices which they used in their most recent projects. Furthermore the participants are made aware that their professional advice of how best to do it will follow soon in another question.

Maturation: The threats here are to keep the interest of the participant while making sure that the participant understands the suggested method. We attempt to motivate the individual participation of each member by offering the thesis result as an opportunity to learn more about FSM. The interviewer demonstrated the new method with an example to which the interviewee can relate to. The interviewer then asks the participant member to provide feedback about their thoughts and concerns of the suggested method, which were used as another method to ensure that the interviewee understood the method.

Mortality: The threat that the interviewee may quit their position before the research is completed, and therefore in consequence there might be no follow-up interview for this participant. By increasing the number of interviews, and arranging for more than one contact person, we were able to reduce this threat.

Statistical Regression: The sample data used to test both the current practices and new method might be incomplete and do not represent all ERP projects. Different methods of interpretation were used and compared to validate the founding's.

Active bias: The interview participants may only be trained to use effort estimations in a certain way labeled as best practice. The participants could therefore withhold valuable information. In this research we made use of observations, interviews from different roles internal and external of SAP AG, to ensure a less bias and validated result. The combination of both the interviews and observations is well aligned with the action research method objective to explore a certain phenomena and reduce the observer and interviewee bias when used in combination.

Sample size: The interview sample size may be too small to represent the SE domain. A reasonable amount of interviews both internal and external of SAP ensure that the sample size is representable for SAP AG and generalizable. Further measures were taken to include two research approaches based on both qualitative and quantitative methods.

11.3. A Comparison between the IFPUG and COSMIC FSM methods

IFPUG	COSMIC
Origins and Current Usage The IFPUG method was the first FSM (Functional Size Measurement) Method. It was developed and heavily promoted by IBM in the early 1980's. It is therefore the most widely used FSM method.	The COSMIC method was developed by an international group of software metrics experts who had been members of the ISO Working Group on FSM. First published in 2000, it is now used all over the world. We do not know the number of users, but the current version and translations of the method definition have been downloaded over 1500 times.
Design The design is based on the concepts of an estimating method that IBM used in the late 1970's. It was calibrated using data from 24 business application (or 'MIS' – Management Information Systems) development projects in an IBM DP Services organization [1].	The design is based on fundamental principles of software engineering and to conform to measurement theory. Consequently, the method is 'future-proof'. All COSMIC 'Guidelines', e.g. for sizing Data Warehouse or SOA software, or for sizing software in Agile projects, simply explain how to apply the existing principles and rules. The

A consequence is that whenever new ways of constructing software are developed, new rules have to be invented to adapt the method.	basic measurement rules have not changed since they were first published.
Applicability The method claims to be applicable to size any software, but note that no FSM Method can properly account for the size of pure mathematical algorithms. For the past 30 years, the IFPUG method has been of very little use outside the MIS world.	The method was designed to be applicable to business application, real-time and infrastructure software and hybrids of these, in any layer of software architecture, at any level of decomposition. It is now widely used in all domains for which it was designed.
Measurement Scale The measurement scale allows only three sizes for any component – low, average or high. This very seriously limits the accuracy of size measurement for large and complex software processes.	The measurement scale is an open-ended ratio scale, as for any normal measurement method. Single functional processes (transactions) have been measured of over 70 CFP in MIS and over 100 CFP in avionics software. The smallest size for a single functional process is 2 CFP.
Measuring the size of changes to software It is not possible to measure the size of a change to a software component with the IFPUG method. It can only be used to measure the size of software components that are added, changed or deleted.	The COSMIC method can be used to measure the size of a change (addition, modification or deletion) to software of one CFP. It can also be used to measure the size of software that is added, changed or deleted.
Accounting for 'Non-Functional Requirements' (NFR) IFPUG has now made the 'Value Adjustment Factor' (which aimed to account for 14 'General Application Characteristics') an optional feature as it is irrelevant to modern software development. But IFPUG is now developing a replacement 'SNAP' (Software Non-functional Assessment Process) size index to account for a selection of 16 NFR. The SNAP index will be as meaningless and useless as the VAF.	COSMIC has always aimed that its FSM method should be based on fundamental software engineering principles. Research has now demonstrated [2] conclusively that the COSMIC method can be used to measure the size of software that results from NFR, e.g. maintainability, operability, usability, portability, etc. A separate size index for NFR is thus unnecessary.
Availability of Benchmark Data As the method has been available for many more years, there are many more IFPUG-measured projects in the ISBSG database than COSMIC-measured projects. However, relatively little of this data is from the last decade and almost all is from the MIS domain.	The ISBSG database now has data on well over 450 COSMIC-measured projects. A COSMIC-ISBSG joint report is available with comprehensive analyses of business, real-time and component software projects. We regularly encourage all users to submit more data.
Use for Project Effort Estimation Formal project estimation models often require a size of requirements to be given in units of Lines of Code or IFPUG Function Points. Researchers have found [3] that in spite of the fact that such estimation models have existed for many years, expert judgment is still the most widely used method of estimation. Further, available evidence suggests that using formal pre-defined estimation models does not improve estimation accuracy compared with using expert judgment.	There are now several reports of COSMIC users building estimating models, or adapting their existing models to use COSMIC sizes and obtaining extremely good estimates. Examples include Sogeti (Netherlands), CSC (India), Ericsson (Italy), Nokia (Finland), NTT (Japan), Rabobank (Netherlands), Renault (France) and Saab/GM, (Sweden). Others have reported excellent results from using COSMIC to estimate User Stories in Agile projects. (Several of the relevant papers are available
Research & Development Over two decades, the IFPUG method has been exhaustively examined by researchers, who have	There is much academic research now focused on the use of the COSMIC method, e.g. for effort estimation, and for automatic COSMIC sizing of requirements.

identified a number of weaknesses, but most of the proposed improvements have not been accepted to update the IFPUG method.	
The 'Bottom Line' – Costs To obtain the IFPUG documentation and to use the method, an organization must become an IFPUG member and pay an annual membership fee. A fee must be paid for taking a certification examination (ca 250 USD per individual); the exam must be re-taken and the fee paid again every three years to maintain the certification.	All COSMIC method standards and related publications are available for free download from www.cosmicon.com. There is no formal membership of COSMIC. Many users have joined the 'COSMIC Size Users' group on Linkedin. A fee must be paid for taking a certification examination (ca 100 USD per individual), but the certification lasts indefinitely.

Table 19: Comparison of IFPUG and COSMIC FSM [61]

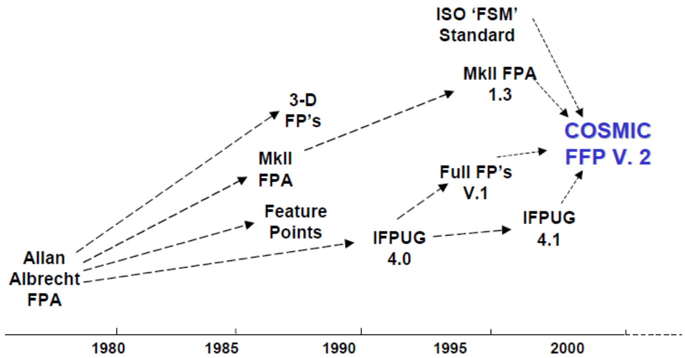


Figure 16: FSM history

PRINCIPLES – The COSMIC Generic Software Model

a) Software receives **input** data from its functional users and produces **output**, and/or another outcome, for the functional users

b) Functional user requirements of a piece of software to be measured can be mapped into unique functional processes

c) Each functional process consists of **sub-processes**

d) A sub-process may be either a data movement or a **data manipulation**

e) Each functional process is triggered by an **Entry** data movement from a functional user which informs the functional process that the functional user has identified an **event**

f) A data movement moves a single **data group**

g) A data group consists of a unique set of **data attributes** that describe a single object of interest

h) There are four types of data movement. An Entry moves a data group into the software from a functional user. An **Exit** moves a data group out of the software to a functional user. A **Write** moves a data group from the software to persistent storage. A **Read** moves a data group from persistent storage to the software

i) A functional process shall include at least one Entry data movement and either a Write or an Exit data movement, that is it shall include a minimum of two data movements

j) As an approximation for measurement purposes, data manipulation sub-processes are not separately measured; the functionality of any data manipulation is assumed to be accounted for by the data movement with which it is associated

Figure 17: The COSMIC generic model [4]

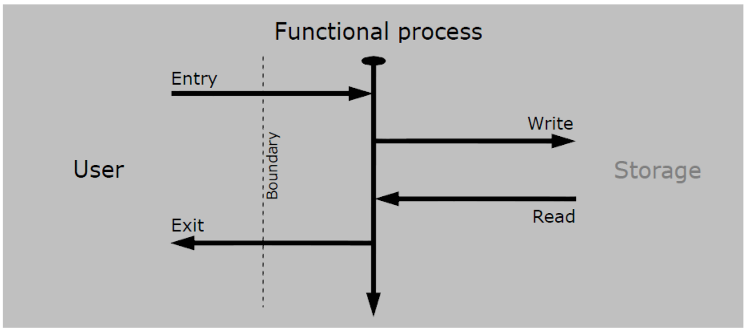


Figure 18: COSMIC data movements [4]

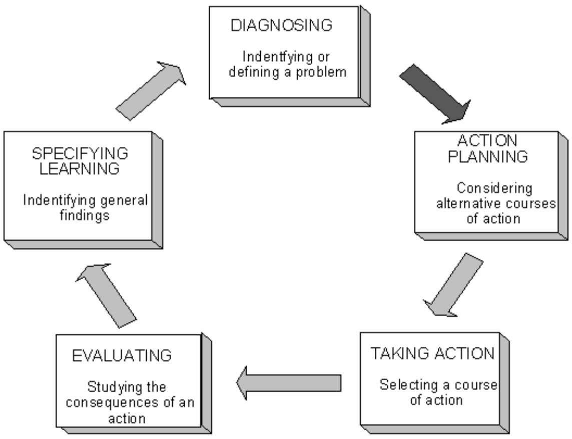


Figure 19: Action Research Approach [15]

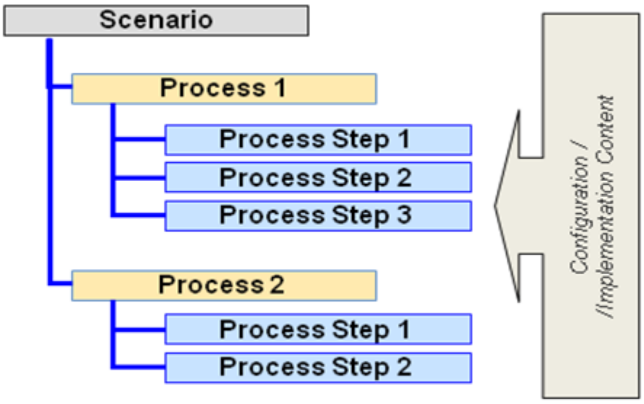


Figure 20: Business Scenario Structure

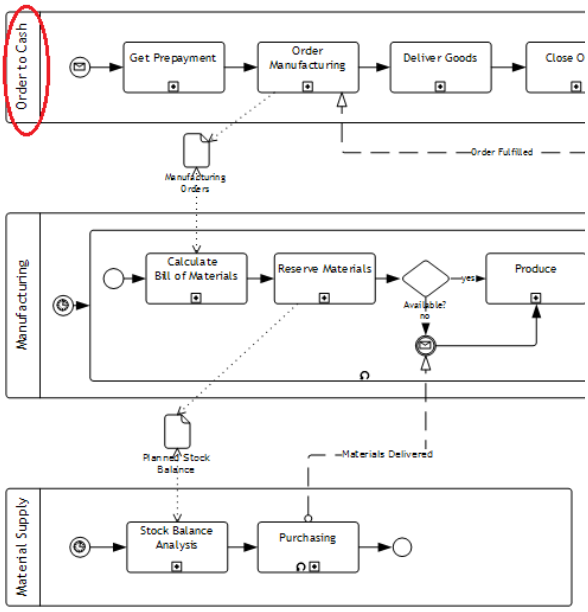
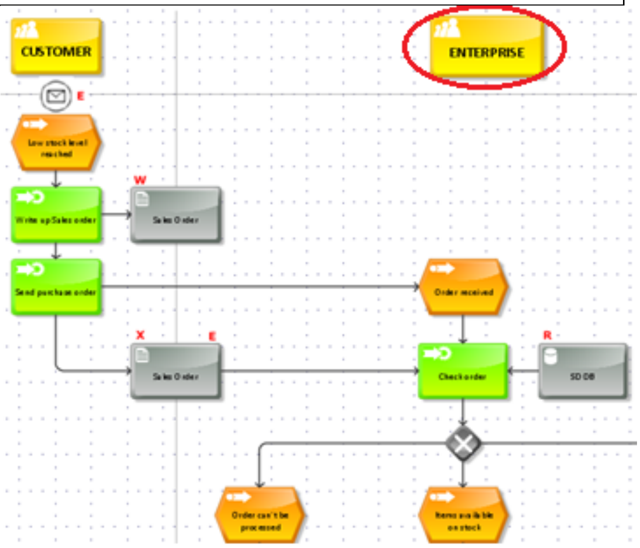
BPMN	ARIS
	

Table 20: Modeling Rule BPMN1

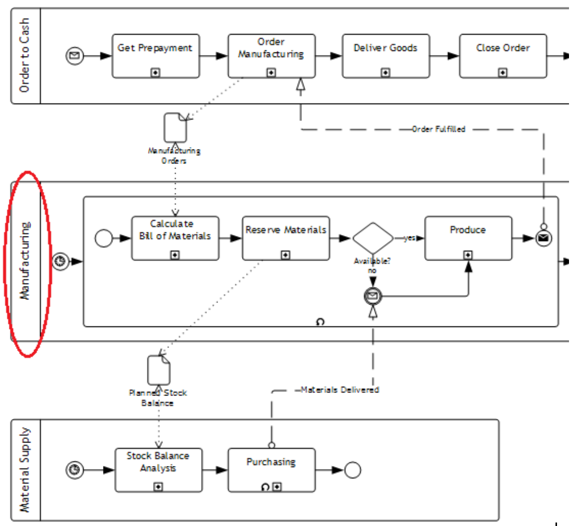
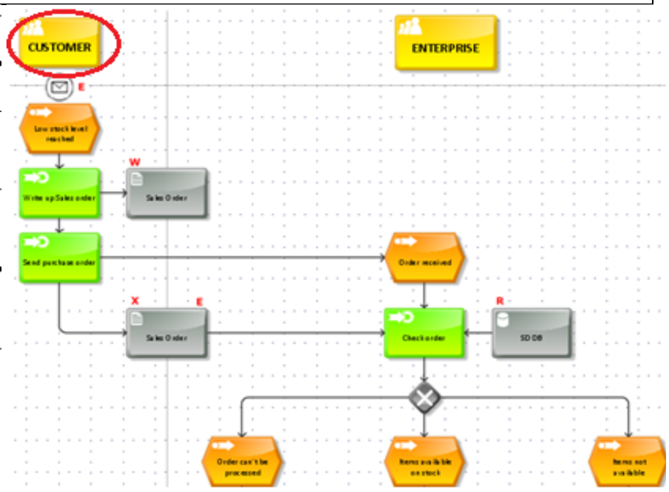
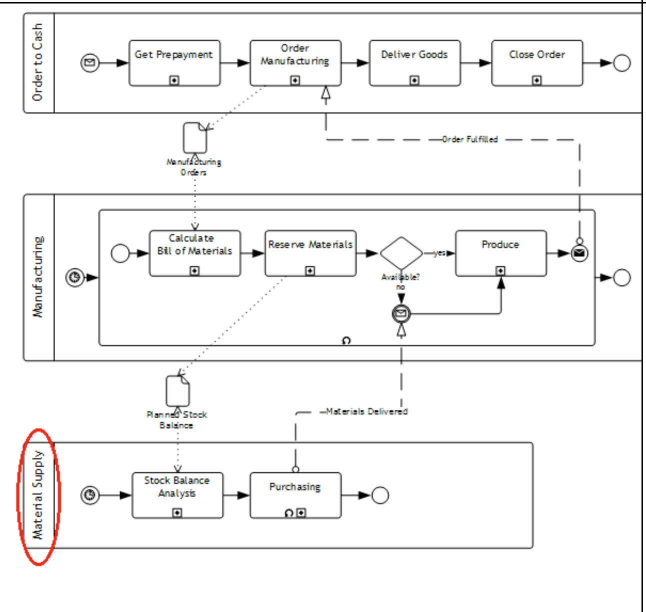
BPMN	ARIS
	

Table 21: Modeling Rule BPMN2

BPMN



ARIS

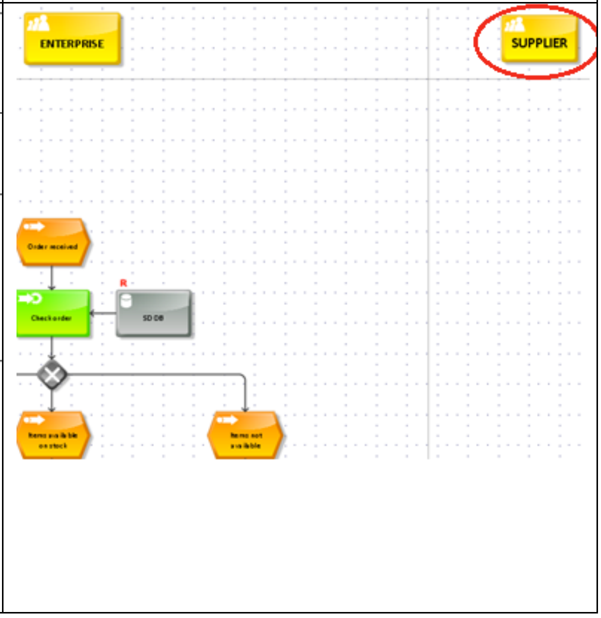
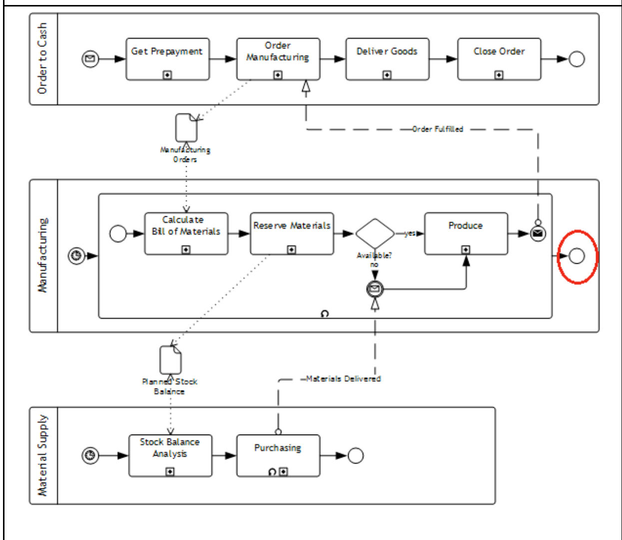


Table 22: Modeling Rule BPMN3

BPMN



ARIS

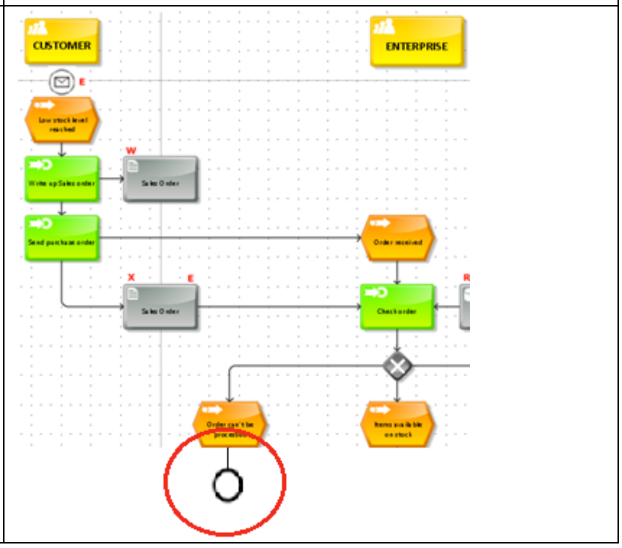


Table 23: Modeling Rule BPMN4

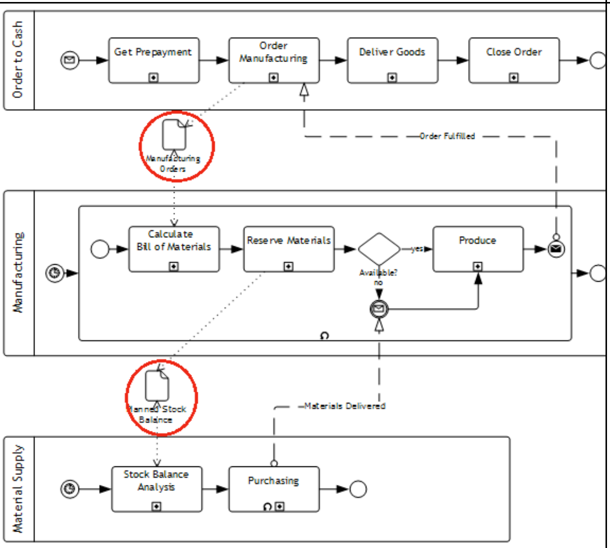
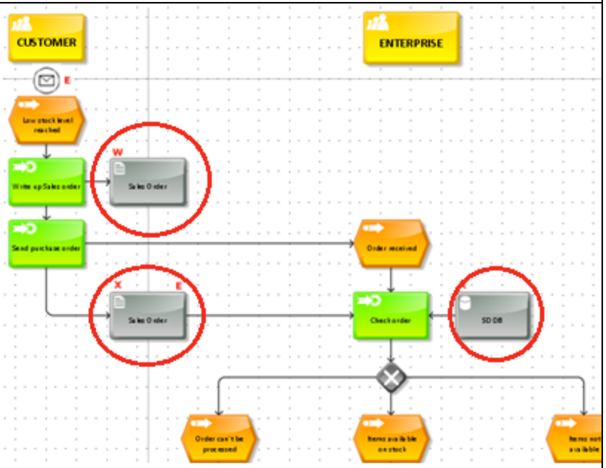
BPMN	ARIS
	

Table 24: Modeling Rule BPMN5

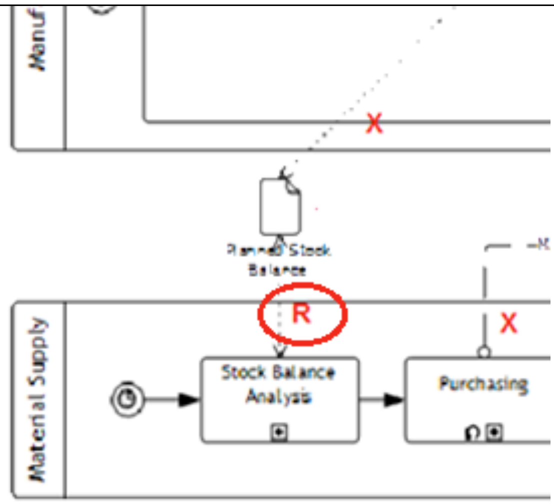
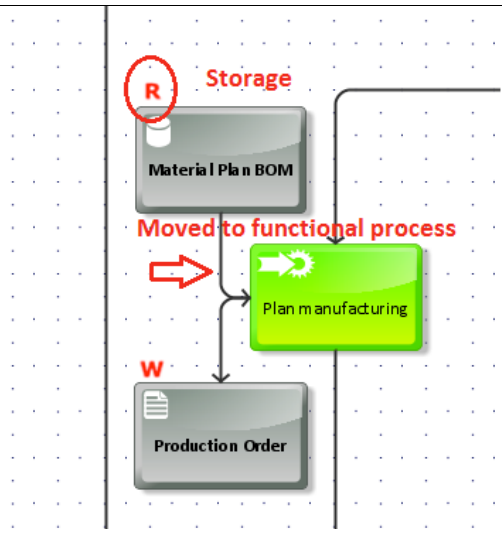
BPMN	ARIS
	

Table 25: Modeling Rule COSMIC3. Read

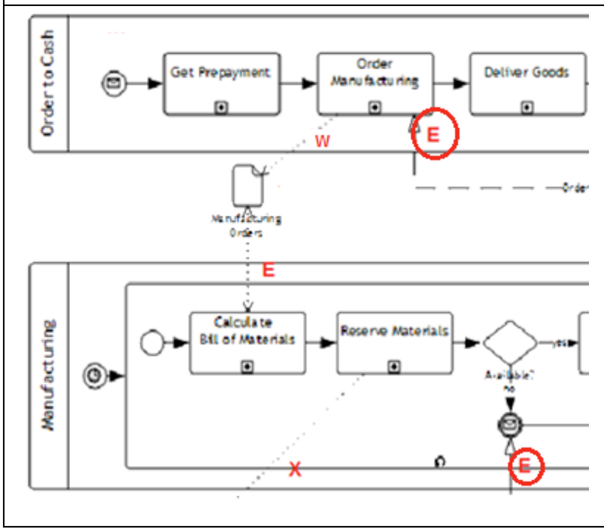
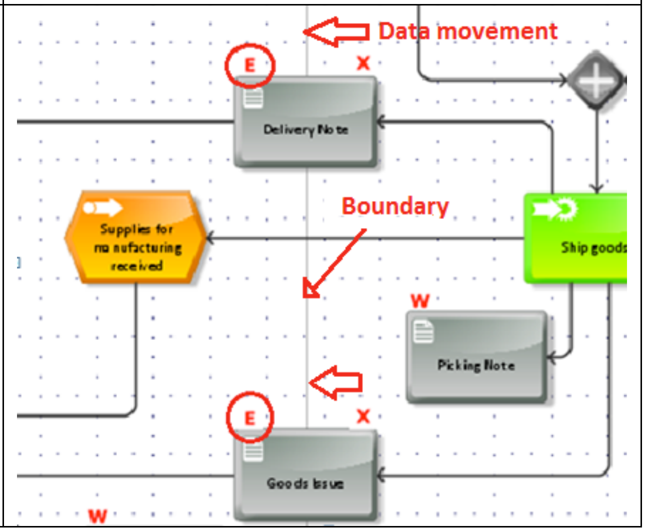
BPMN	ARIS
	

Table 26: Modeling Rule COSMIC1- Entry

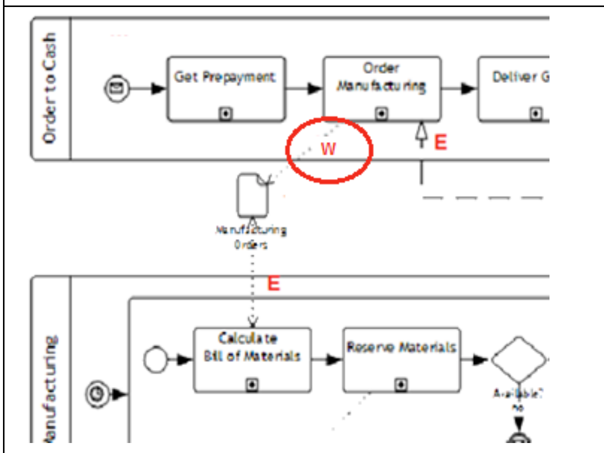
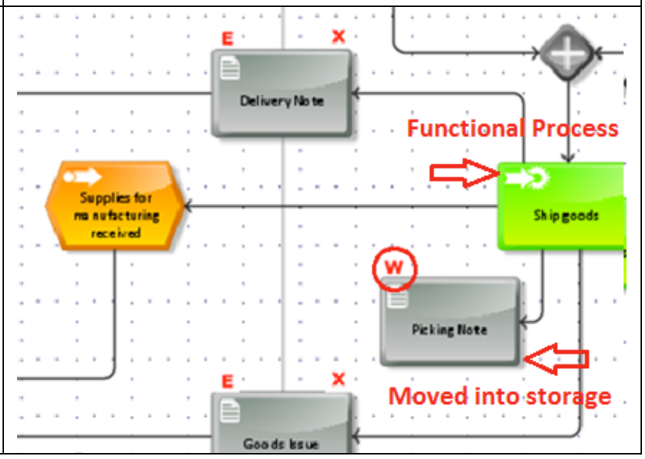
BPMN	ARIS
	

Table 27: Modeling Rule COSMIC2 -Write

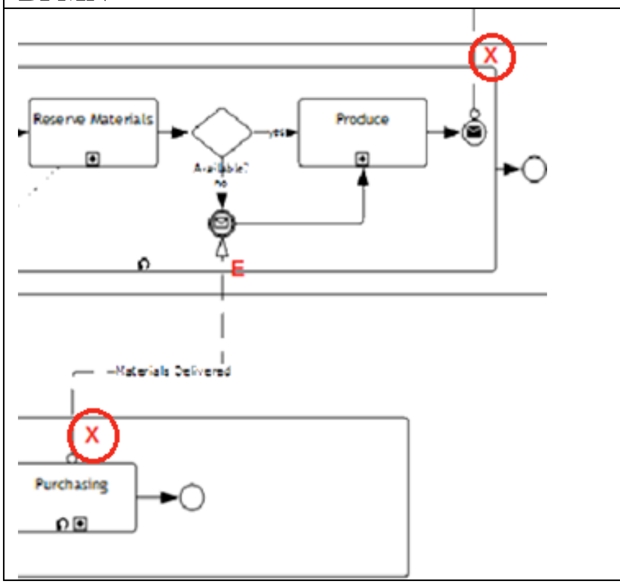
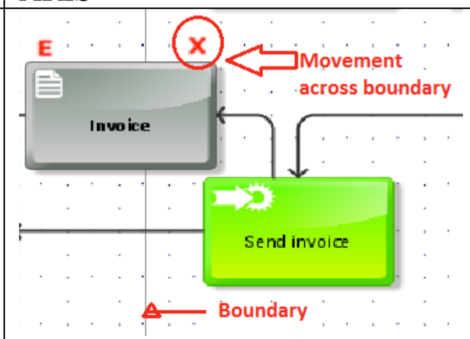
BPMN	ARIS
	

Table 28: Modeling Rule COSMIC4. EXIT

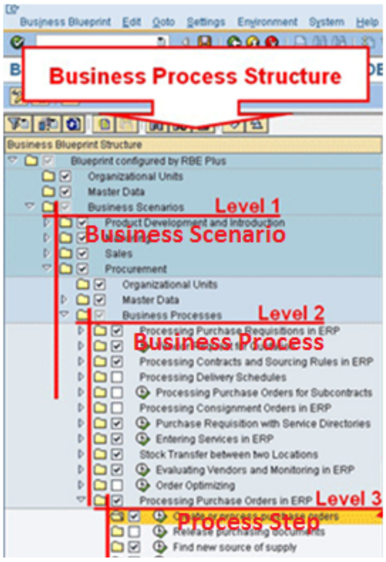


Figure 21: ASAP Solution Manager Process Structure

# Install	Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
Install J57	**Procurement process overview**	1		YES		21		7	7	14	10	52
Install J57	**Production order process overview**	1		NO								
Install J57	**Inventory management** overview	1		NO								
Install W40	**Order to cash** process overview	1		YES		18		7	6	5	11	**51**
Install W40	**1.1. Customer Master Data**	2		YES		3	YES	1	1	1	2	**15**
Install W40	1.1.1. Create Customer	3	SD	YES	NO		YES	1			1	
Install W40	1.1.2. Extend Customer master data	3	SD	YES	NO		NO				1	
Install W40	1.1.3. Display Customer master Record	3	SD	YES	NO		NO		1	1		
Install J57	**1.2. Sales conditions**	2		YES		2	NO	0	0		0	**0**
Install J57	1.2.1. Create product specific condition record	3	SD	YES	YES		NO	0			0	
Install J57	1.2.2. Create customer specific condition record	3	SD	YES	YES		NO		0		0	
Install J57	**1.3. Sales Order Management**	2		YES		1	NO	0	0		0	**0**
Install J57	1.3.1. Create a sales order	3	SD	YES	YES		NO	0	0		0	
Install W40	**1.4. Material requirements Planning**	2		NO		**0**	NO	1	1	1	2	**0**
Install J06	1.4.1. Check MRP status	3	MM	NO	NO		NO	1			1	
Install J06	1.4.2. Carry out MRP	3	MM	NO	NO		NO				1	
Install J06	1.4.3. Display stock/requirements list	3	MM	NO	NO		NO		1	1		
Install W40	**1.5. Producing Item**	2		YES		4	NO	1	1		2	**4**
Install J06	1.5.1. Create production orders	3	PP	YES	NO		NO	1			1	
Install J06	1.5.2. Purchase material	3	MM	YES	NO		NO		1		1	
Install J06	1.5.3. Enter goods issue	3	PP	YES	NO		NO		1		1	**2**
Install J06	1.5.4. Confirmation of production order	3	PP	YES	NO		NO		1		1	
Install W40	**1.6. Shipping Processing**	2		YES		4	YES	1	1	1	2	**20**
Install W40	1.6.1. Create delivery	3	SD	YES	NO		NO	1			1	
Install W40	1.6.2. Picking	3	SD	YES	NO		NO				1	
Install W40	1.6.3. Enter goods Issue	3	SD	YES	NO		YES			1		
Install W40	1.6.4. Display documentation flow	3	SD	YES	NO		NO		1			
Install W40	**1.7. Billing**	2		YES		1	YES	1	0	0	1	**2**
Install W40	1.7.1. Create Billing document	3	SD	YES	NO		YES	1			1	
Install W40	1.7.2. Display document flow	3	SD	NO	NO		NO		1	1		
Install W40	**1.8. Incoming Payment**	2		YES		1	NO	1	1	1	1	**4**
Install Base	1.8.1. Enter incoming payment	3	FI	YES	NO		NO	1	1		1	
Install W40	**1.9. Reporting**	2		YES		2	NO	1	1	1	1	**4**
Install W40	1.9.1. Display sales order	3	SD	YES	NO		NO	1		1		
Install W40	1.9.2. Carry out standard analysis	3	SD	YES	NO		NO		1		1	
	SUMMARY											**103**

Figure 22: COSMIC EPC model version 2, (Order to Cash - Business Process)

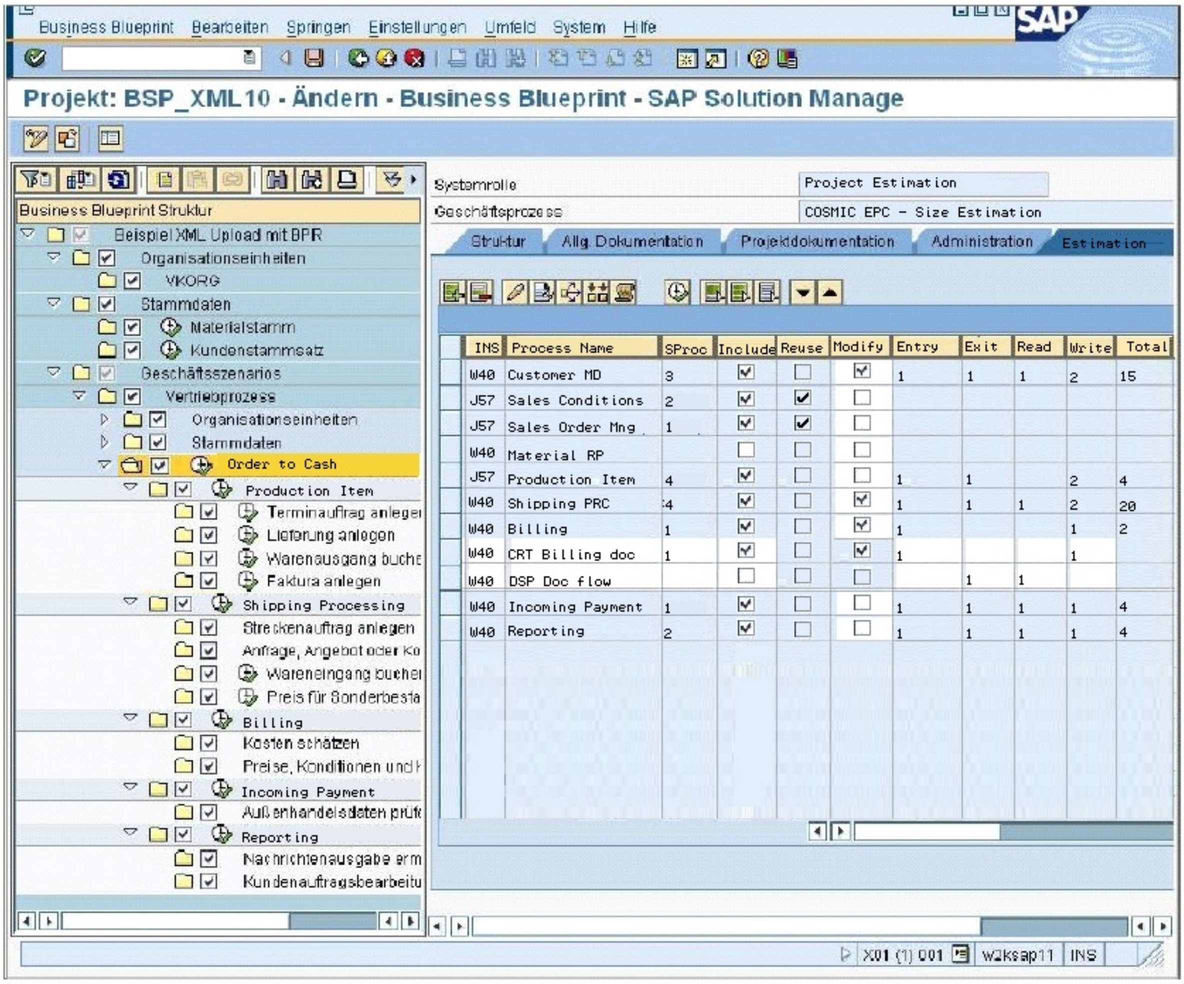


Figure 23: SAP interface Prototype (Add-on functionality) for the ASAP Solution Manager

Business Process / Function	Entry	Exit	Read	Write	Total
1. **Order to cash** business scenario					
1.1. Customer Master Data					
1.1.1. Create Customer	1			1	2
1.1.2. Extend Customer master data				1	1
1.1.3. Display Customer master Record		1	1		2
1.2. Sales conditions					
1.2.1. Create product specific condition recor	1			1	2
1.2.2. Create customer specific condition record		1		1	2
1.3. Sales Order Management					
1.3.1. Create a sales order	1	1		1	3
1.4. Material requirements Planning					
1.4.1. Check MRP status	1		1		2
1.4.2. Carry out MRP				1	1
1.4.3. Display stock/requirements list		1	1		2
1.5. Producing Item					
1.5.1. Create production orders	1	1		1	3
1.5.2. Purchase material	1	1	1		3
1.5.3. Enter goods issue	1			1	2
1.5.4. Confirmation of production order		1		1	2
1.6. Shipping Processing					
1.6.1. Create delivery	1			1	2
1.6.2. Picking				1	1
1.6.3. Enter goods Issue			1		1
1.6.4. Display documentation flow		1	1		2
1.7. Billing					
1.7.1. Create Billing document	1			1	2
1.7.2. Display document flow		1	1		2
1.8. Incoming Payment					
1.8.1. Enter incoming payment	1	1		1	3
1.9. Reporting					
1.9.1. Display sales order	1		1		2
1.9.2. Carry out standard analysis		1		1	2
Total	**11**	**11**	**8**	**14**	**44**

Table 29: COSMIC EPC – Order-to-Cash- scenario estimate

Business Process	Level	Module	Include	Reuse	# SubPr	Modify	Entry	Exit	Read	Write	Total
Order to cash process overview	1		YES		18		7	6	5	11	51
1.1. Customer Master Data	2		YES		3	YES	1	1	1	2	15
1.1.1. Create Customer	3	SD	YES	NO		YES	1			1	
1.1.2. Extend Customer master data	3	SD	YES	NO		NO				1	
1.1.3. Display Customer master Record	3	SD	YES	NO		NO		1	1		
1.2. Sales conditions	2		YES		2	NO	0	0		0	0
1.2.1. Create product specific condition record	3	SD	YES	YES		NO	0			0	
1.2.2. Create customer specific condition record	3	SD	YES	YES		NO		0		0	
1.3. Sales Order Management	2		YES		1	NO	0	0		0	0
1.3.1. Create a sales order	3	SD	YES	YES		NO	0	0		0	
1.4. Material requirements Planning	2		NO		0	NO	1	1	1	2	0
1.5. Producing Item	2		YES		4	NO	1	1		2	4
1.5.1. Create production orders	3	PP	YES	NO		NO	1			1	
1.5.2. Purchase material	3	MM	YES	NO		NO		1		1	
1.5.3. Enter goods issue	3	PP	YES	NO		NO		1		1	2
1.5.4. Confirmation of production order	3	PP	YES	NO		NO		1		1	
1.6. Shipping Processing	2		YES		4	YES	1	1	1	2	20
1.6.1. Create delivery	3	SD	YES	NO		NO	1			1	
1.6.2. Picking	3	SD	YES	NO		NO				1	
1.6.3. Enter goods Issue	3	SD	YES	NO		YES			1		
1.6.4. Display documentation flow	3	SD	YES	NO		NO		1			
1.7. Billing	2		YES		1	YES	1	0	0	1	2
1.7.1. Create Billing document	3	SD	YES	NO		YES	1			1	
1.7.2. Display document flow	3	SD	NO	NO		NO		1	1		
1.8. Incoming Payment	2		YES		1	NO	1	1	1	1	4
1.8.1. Enter incoming payment	3	FI	YES	NO		NO	1	1		1	
1.9. Reporting	2		YES		2	NO	1	1	1	1	4

Figure 24: Order-to-Cash effort estimation example

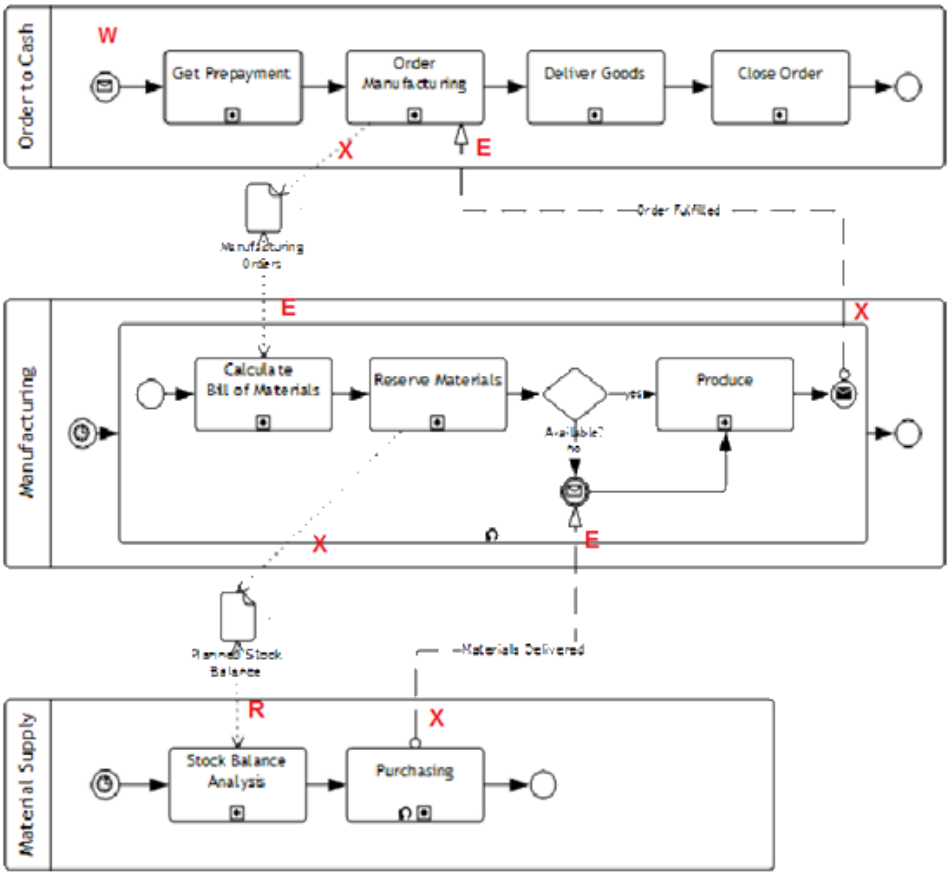


Figure 25: COSMIC EPC applied to BPMN 1.2 model

Project	1	2	3	4	5	6	7	8	9
Size	26	32	39	21	34	27	71	52	38
Unit cost	1350,00	1100,00	1100,00	2500,00	1350,00	1100,00	1350,00	550,00	1350,00
Level	Level 3	Level 2	Level 2	Level 5	Level 3	Level 2	Level 3	Level 1	Level 3
Conversion	0,90	1,10	1,10	0,60	0,90	1,10	0,90	1,60	0,90

Table 30: COSMIC EPC Calculation Data

X-does not support	Interviewee does not agree
√ - participate	Interviewee agree with some uncertainty
√√ - make a good impact	Interviewee agree with surety
√√√ - extraordinary contribution	Interviewee agree strongly

Table 31: Level of agreement

11.4. Exploring process customization

The relationship between process modification and functional size are displayed in Figure 26: Process Customization. This diagram shows that as the process modifications increase so does the functional size of the project. Therefore we can say that the process modification (also referred to as customization) has an exponential impact on the project function size.

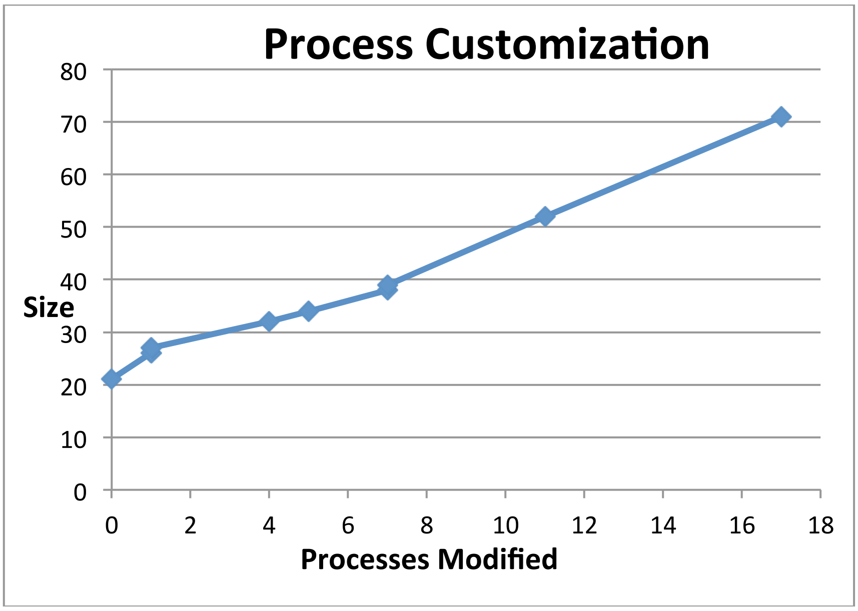


Figure 26: Process Customization

11.5. The evaluation of time, cost, size, process reuse and modification.

In the following Table 32: Relative Project Estimation values, we calculate the approximate value of the original key figures displayed in Table 16. By dividing each figure with the highest value in its series (Time, Cost, Size...etc). We are able to calculate the approximate value for each project related to each series. The approximate values enable us to compare the different parameters; time, cost, size, reuse and modification series to establish the relationship between them.

	Project1	Project2	Project3	Project4	Project5	Project6	Project7	Project8	Project9
Time	0,49	0,59	0,71	0,24	0,54	0,56	1,00	1,27	0,68
Cost	0,49	0,48	0,58	0,45	0,54	0,46	1,00	0,52	0,68
Size	0,37	0,45	0,55	0,30	0,48	0,38	1,00	0,73	0,54
Reuse	0,14	0,29	0,57	0,29	0,57	0,29	1,14	0,71	1,00
Modify	0,06	0,24	0,41	0,00	0,29	0,06	1,00	0,65	0,41

Table 32: Relative Project Estimation values

11.6. Process modification, Size and Reuse.

The following diagram Figure 27 provides a high level overview of the relationships between the parameters listed above. In this diagram we are particularly interested in the relationship between Modify (Process Customization), Size (Functional Size) and reuse (Process Reuse).

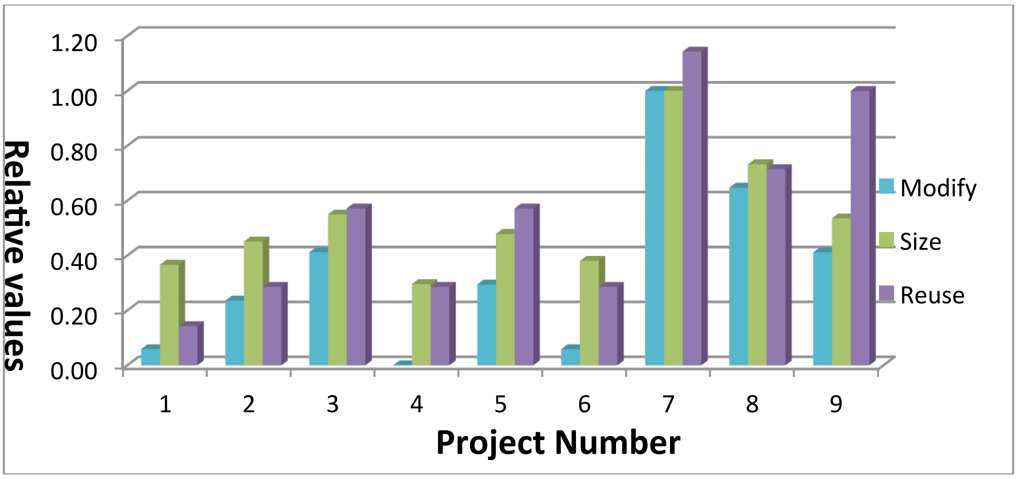


Figure 27: Process Reuse, Modification and Size comparison

In the diagram above Figure 27 we witness a new behavior which the Modify criteria (Process customization) have on the project functional size. In chapter 11.4 we identify that modification (customization of processes) has a positive exponential impact on the size (functional size) of the BP. This is true for the majority of the sample project 1, 2, 4, 5 and 6. For project 8 and 9 we do recognize the positive impact which the Modify criteria has on Size but not exponential in nature, while project 7's Modify criteria has almost no impact on the Size criteria and project 3 appear to have a negative impact. It became clear to us that whenever the criteria Reuse (Process Reuse) appear to a large extent (almost double in comparison to the Modify criteria), it shown to have a negative impact on the Size criteria.

Therefore we can conclude that the Modify (Process customization) criteria has a positive exponential impact on the Size criteria (functional size) while the Reuse criteria (Process Reuse) has a negative impact on the Size criteria.

11.7. Functional Size, Time and Cost.

The following diagrams present the representation of the relative values of Size, Time and Cost per project.

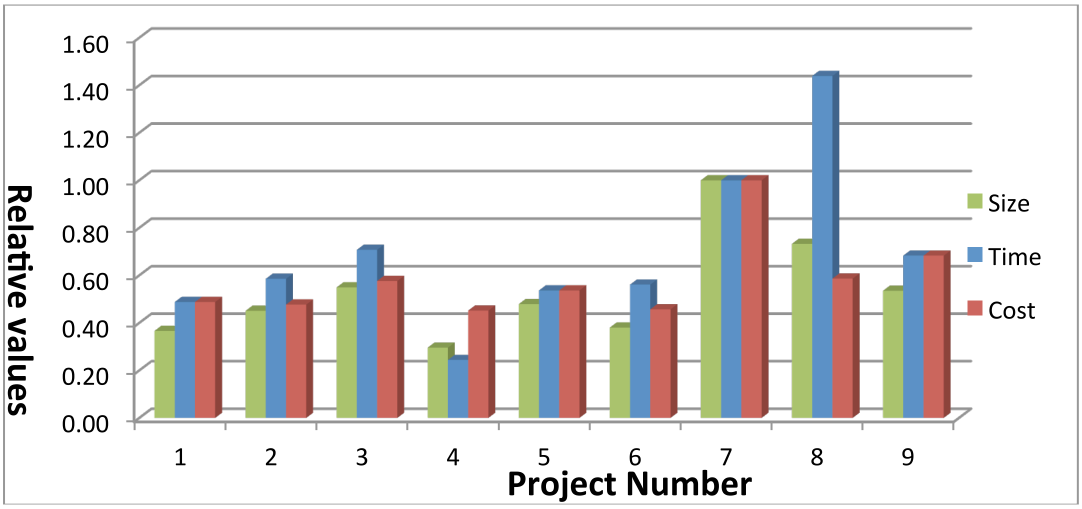


Figure 28: Project Size, Time and Cost comparison

In the diagrams above Figure 28 and Figure 29, we witness the relative relationship between size, time and cost where in most cases cost and time are positively affected by the size criteria. The relationship between cost and time are those of compensation.

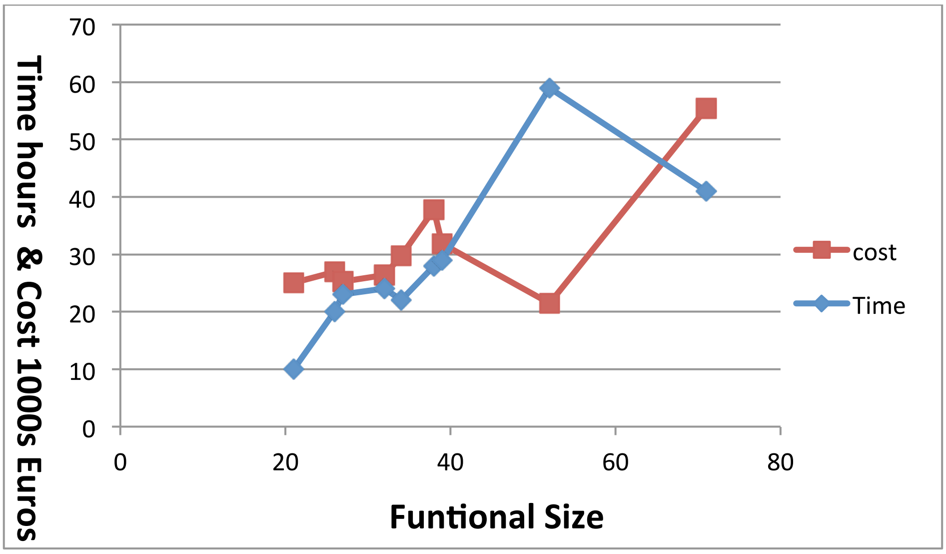


Figure 29: Project Cost and Time comparison

Wherever the time factor were drastically longer, we witness a lower cost in relation to the size factor (Project 8 -Figure 29). In retrospect whenever the cost in relation to the size factors was significantly larger we experienced a decrease in time (Project 4 - Figure 29).

11.8. Functional Size, Cost, Reuse and Customization.

In the following section we display a comparative evaluation of the nine ERP projects in order from the smallest to the biggest functional size with its related time, cost, modify (process customization) and reuse (process reuse) criteria.

Project	Size	Time	Cost	Modify	Reuse
Project 4	0,30	0,24	0,45	0,00	0,25
Project 1	0,37	0,49	0,49	0,06	0,13
Project 6	0,38	0,56	0,46	0,06	0,25
Project 2	0,45	0,59	0,48	0,24	0,25
Project 5	0,48	0,54	0,54	0,29	0,50
Project 9	0,54	0,68	0,68	0,41	0,88
Project 3	0,55	0,71	0,58	0,41	0,50
Project 8	0,73	1,44	0,39	0,65	1,13
Project 7	1,00	1,00	1,00	1,00	1,00

Table 33: Relative Project values

The following diagram Figure 30 evaluates the relationship between the relative values of cost, reuse, process customization and reuse.

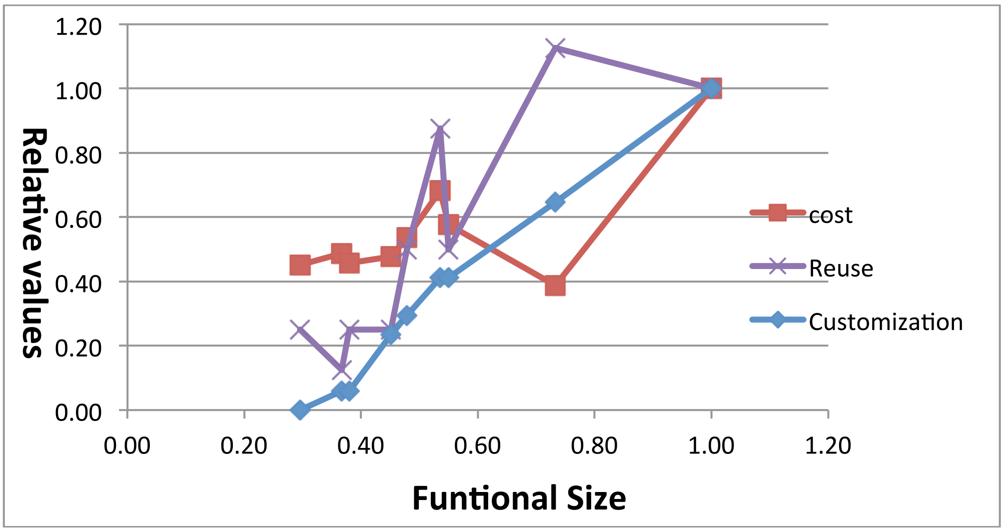


Figure 30: The approximate relationship of cost, size, process customization and reuse

The 6 projects with the smaller size values (Approximate Functional Size values of 0,30 to 0,50), where process reuse and customization are relatively balanced (equal in relation to their relative values); process customization show a constant positive impact on the functional size and project cost. What is new to this diagram is that with the 7th and 8th biggest projects (Approximate Functional Size values from 0,60 upwards), we experience a sudden drop in cost while the customization remain in a slower positive growth. It came clear to us that when there was a sudden increase in process reuse, while the process customization appears relatively smaller in comparison to process reuse, the cost drop significantly.

In practical terms its seems logical that when the ERP implementation reuse certain processes to a larger extend while maintaining a lower degree of customization of these processes, it will decrease the cost of effort in comparison to a project where the process customization is to a larger extend, while not making reuse of repeated processes.

11.9. ERP industry impact

This thesis provides both evidence and support to the statements made by the latest Gartner reports discussed below.

One of the Gartner reports stipulate that 80% of all ERP implementations exceed time and budget estimates [57]. These figure are well aligned with the thesis's statistics in chapter Evaluation of the Expert Judgment method6.2.1 which indicate that 7 out of 9 (77%) of the past projects were running overtime and over budget using the expert judgment method.

Gartner wrote that ERP project success requires a focus on business processes, in terms of software functionality. They wrote that ignoring these aspects will cause your project to fail [57]. The thesis demonstrates the use of business processes to reassure the inclusion and exclusion of only the processes in the project scope.

Gartner wrote that among the key success factor is to minimize modifications, and build a business case for each required modification [57]. The thesis support this comment by demonstrating the affect that modifications have on the project scope, cost and time and ignoring this during effort estimation could almost guarantee ERP project failure.

Gartner further wrote in a report called: Best practice -five action items to improve your domestic ERP implementation projects, to focus on using methods, templates and accelerators (like the SAP ASAP tool) that increase quality, speed up the implementation process, reduce costs and mistakes, and improve consistency [62]. The COSMIC EPC method supported with its add on functionality for the ARIS EPC and ASAP solution supports the five recommended best practice items which aim is to increase quality and accurateness of effort estimates which could affect the total amount of successful ERP implementations.

Gartner also wrote in the: Magic quadrant for ERP product centric midmarket companies; that SAP Business R3 is the strongest solutions in the market [63], therefore suggest that if the COSMIC EPC method is tailored for the SAP ERP brand, that it could possibly be generalized and used across the ERP industry.

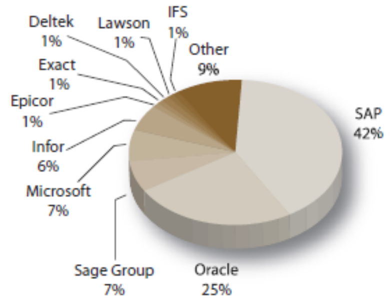


Figure 31: AMR Research ERP market share [56]

11.10. ERP project duration impact

The independent research group Panorama stated that 35,5% of all ERP projects run over time.

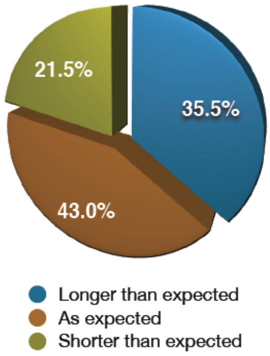


Figure 32: ERP projects time overrun [59]

In a comparison between the three largest providers SAP, Oracle and Microsoft nearly two-thirds (61%) of respondents indicated that their implementations had gone over schedule, while only 8% completed implementations earlier than scheduled [64].

Duration Findings	
Earlier than scheduled	8%
Over-schedule	61%
On-schedule	31%

Figure 33: ERP duration overruns [64]

Oracle implementations take longer than expected 75% of the time. Microsoft projects take longer than expected 47% of the time. SAP implementations take about 61% longer than expected. Although SAP implementations have similar risk, SAP customers are typically larger and manage more complexity [64].

The main reasons for running overtime is reported and displayed in Figure 34. In short the COSMIC EPC method could account to address at least 36% of those problems where the technical issues only account of 7%. The problem areas where the COSMIC EPC method could assist with are: Expanded project scope which is not accounted for 17%, conflicts in priority of project due to complexity issues 10% and unrealistic planning 9% [64].

Reasons Behind Extended Durations	
Initial Project Scope was Expanded	17%
Organizational Issues	14%
Data Issues	14%
Resource Constraints	13%
Conflicts in Priority of Project	10%
Training Issues	10%
Unrealistic Timeline	8%
Vendor Functionality Issues	8%
Technical Issues	7%

Figure 34: Reasons of extended durations [64]

11.11. ERP project budget impact

The difference between budgeted costs and actual costs is a major issue for most companies implementing ERP software packages. In a industry study over half (51.4%) of the respondents indicated their actual costs were over budget, 40% were on budget, and only 8.6% came in under budget [58].

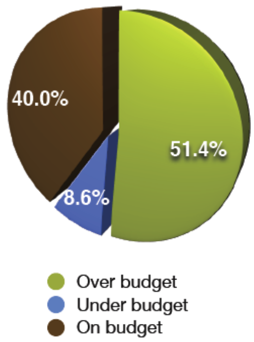


Figure 35: ERP budget overrun [58]

For the large and complex ERP vendors (category Tier1) which SAP, Oracle and Microsoft belong to; show that 53% of all ERP projects are running over budget.

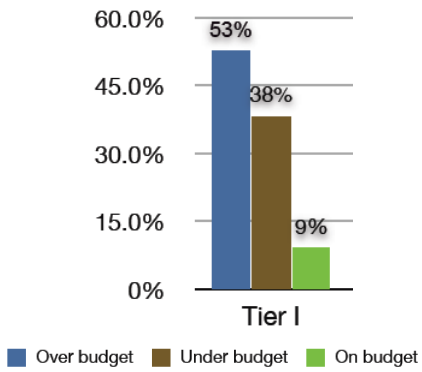


Figure 36: ERP Tier I budget overrun [58]

The majority of the reasons why the projects run over budget where the COSMIC EPC method could improve on are reported in Figure 39 as: consulting fees under estimations 14%, unanticipated technical complexity 19% and expanded project scope 32% [58]. The COSMIC EPC method could reduce as much as 65% of these project budget overruns.

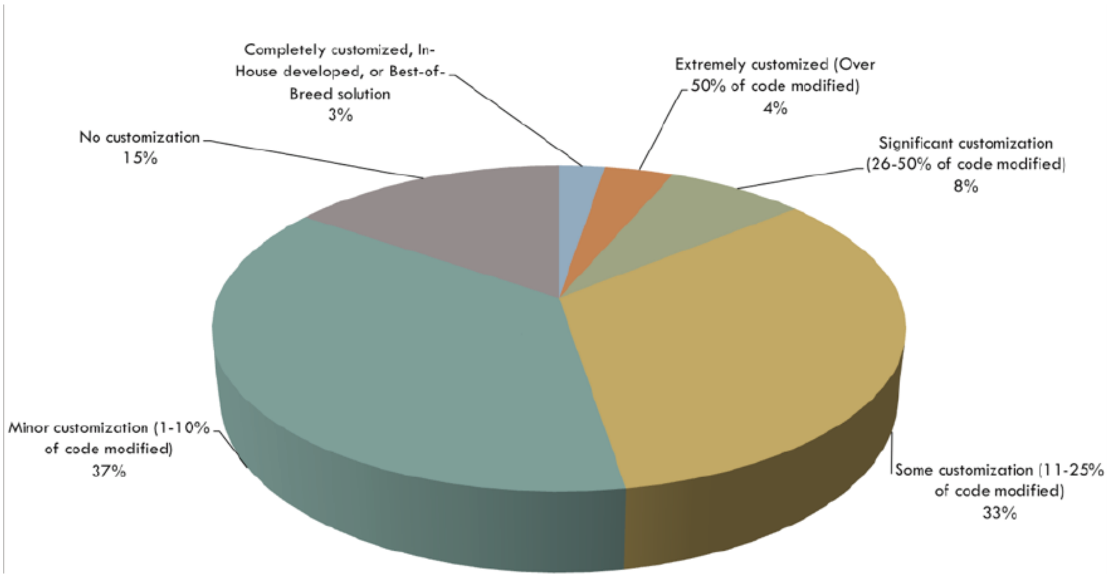


Figure 37: ERP System Level of Customization [59]

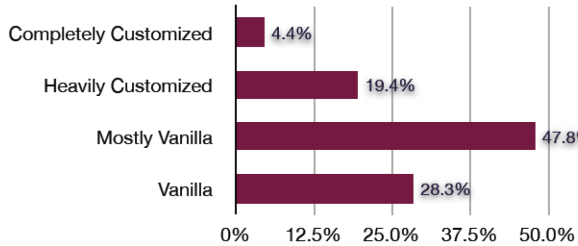


Figure 38: ERP process customization [59]

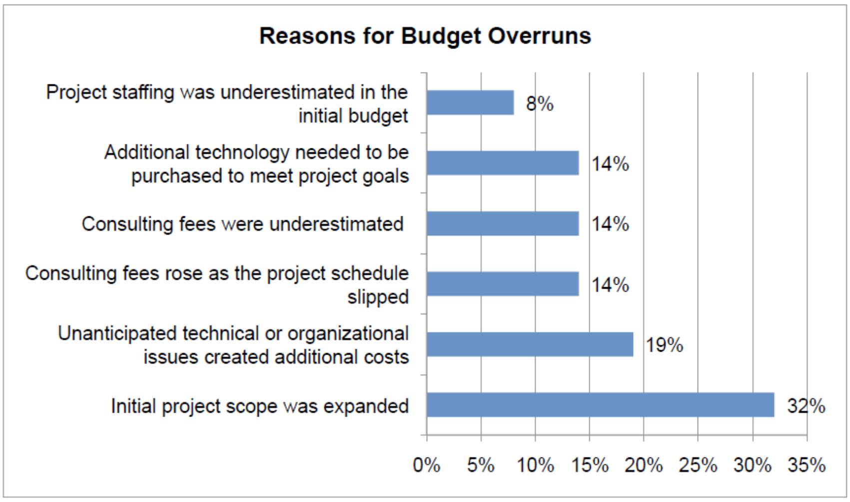


Figure 39: Reasons for ERP budget overruns [58]

11.12. ERP legal impact

Legal law suits between ERP vendors and their clients have cost several millions of Euros and huge brand damages in the last 10 years. In the following section we describe some of those law suits which could be avoided by making use of effort estimation methods that could predict more accurate time and cost estimations. By providing more accurate estimates the ERP client knows what to expect and plan accordingly. The COMIC EPC method can take these complexities into account and could provide more accurate effort estimations where other methods such as expert judgment have failed. The five law suit cases are shortly described below:

Case 1: 2009 SAP and Axon City of San Diego
The city of San Diego, CA terminated its software implementation contract with services provider, Axon, citing "systematically deficient project management practices" and a project that was running $11 million over budget [65].

Case 2: 2008 SAP Waste Management
Waste Management organization wanted an ERP package that could meet its business requirements without large amounts of custom development. The ERP vendor provided more customization than required by the client [66].

Case 3: 2008 SAP City of Portland
A SAP project at the City of Portland municipality, budgeted at $31 million in 2006 for a 2007 go-live date, increased cost to $50 million with the same requirements. Portland has fired its systems integrator, Ariston Technologies and Consulting, and is working directly with SAP services to get the system up and running [67].

Case4: 2003 EDS British Sky Broadcasting
Sky has alleged that EDS exaggerated its abilities and resources when bidding for the contract, resulting in late delivery of the project and lost benefits that make up too £709m in damages it is claiming [68].

Case5: 2001 SAP (R/3) and Accenture FoxMeyer Corp.
The FoxMeyer Corp company claimed that a SAP R/3 implementation in the mid-1990s ruined the company, driven the company to bankruptcy my under estimating the costs of the project. Six years later the bankruptcy trustee and Accenture settled out of court and the lawsuit was dismissed on August 8, 2002 [31].