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OPEN-SOURCE ERP SYSTEM SELECTION: FUZZY MCDM BASED ON ISO 25022 AND COCOMO II FOR COMPANY XYZ

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ABSTRACT

In *Enterprise Resource Planning* (ERP) *implementation* project, selecting the most suitable system become the very critical task. The selected system should completely provide all the modules which support the necessary *business process* (BP) requirement. *Customization* will be needed to bridge the gap between the system and the business needs.

Ultimately, this study's goal is to proposed a new method of ERP selection through the integration of existing methods. Nevertheless, to meet all the company XYZ, a cereal *manufacturing*'s requirements from the technical and investment perspectives. It is assumed that both perspectives are equally important to the company. The research is limited to a fixed BP without Business process Reengineering (BPR), only *open-source* ERP systems as alternatives, and functional and direct investment cost variables.

Several tools and methods are combined to help company XYZ's *IT project*. *Fuzzy Sets Theory* as the main *Multi-criteria decision making* (MCDM) for final output of the procurement. The findings will be confirmed by the experts. Most variables will be adopted from *ISO/IEC 25022*. Their measurements will be combined with *Cost Construction Model* (COCOMO II) cost drivers and *BP* gap as the result of measuring the scope of work. The *BP similarity* will only evaluate the critical workflow of the manufacturing company.

Keywords: ERP, selection, implementation, IT project, manufacturing, business process, similarity, fuzzy, MCDM, ISO 25022, COCOMO II, customization, procurement management

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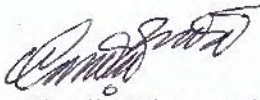

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CHAPTER I
INTRODUCTION

This chapter demonstrates the background of the research, purpose, benefit, contribution, scope, and structure of the documentation. It is to help understand clarify the vision, mission and goals of the research. The chapter ultimately explains the importance and the impact. For further details will be described at the next chapters.

1.1 Background

In 2007, Tata Consultancy services ranked negative outcomes of *Information Technology* (IT) project failures. The top four outcomes were 62% of the project failed to deliver based on schedule, 49% unable to stay within the budget, 47% misestimated the maintenance cost, and 41% fall short delivering the expected value and *return on investment* (ROI) (Kaur & Sengupta, 2011). Just like any other tangible project, IT project always constrained by time, cost, quality, and scope (PMI Inc., 2013). These are also the same issue faced by *Enterprise Resource Planning* (ERP) project. Optimizing cost and benefit for ERP implementation into the organization. Benefit through selecting the appropriate system should minimalize scope of work, cost of construction, and time to implement.

ERP is a collection of software application used to manage and integrate all business activities from the front to the back-end (Magal & Word, 2012). ERP adoption are increasing and become the top five IT priorities among mid-large size companies around the world (Haddara, 2014). Matter of fact, small organization also able to see that ERP can be beneficial for their businesses. However, trade value between return and cost is still a question to them.

Skillful *project management (PM) team* is needed to ensure the successfulness of ERP implementation (Magal & Word, 2012). The project management team responsible to oversee the project from planning to closing. Organization who adopted ERP went through several phases. The phases of the

project are: system selection, implementation, monitor and control the *business process change* (BPC), and evaluate the system afterward (Wei & Wang, 2004).

Most business failed to reap the benefit of ERP due to poor selection method and cost management (Aloini, Dulmin, & Mininno, 2012). Poor selection method is the responsibility of the PM team as part of the planning phase. This problem has raised concern due to the financial damages that most businesses has suffered from. As result, this has attracted scholars to research more in ERP selections shown in Table 2.13.1 and Table 2.13.2. The proposed method in this paper is selected in regards to the system functionality and investment.

System selection is a crucial phase in determining the success of ERP implementation (Haddara, 2014). ERP implementation failure is relatively high, ranging from 40 to 70 percent (Pacheco-Comer & Gonzales-Castolo, 2012). Previous scholars identified failure to select appropriate system as the risk factor with the highest frequency rate which threat the ERP implementation successfulness (Aloini, Dulmin, & Mininno, 2012). The process of documenting the selection of the system is a part of the planning in procurement management which is one of the ten project management bodies of knowledge (PMI Inc., 2013). It is part of the PM team responsibility to plan the system procurement and estimate the cost of customization. COCOMO *II* often used to estimate IT project cost (Boehm, 2000). This method has not yet been implemented to select ERP software based on previous study. The method perhaps can be elaborated by measuring the BP gap between each alternatives to the BP current state.

Company XYZ wanted to adopt ERP system. It is a cereal manufacturing company with a complex *business process* (BP). The business activities will definitely fit into SAP ERP system and other leading ERP software systems. For example, the business activity from order to cash *Business Process* (BP) as shown in *Figure 1.1.2* and this process is a small part in Company XYZ as in *Figure 1.1.1*. However, the acquisition cost of SAP ERP system is out of their budgets. It is ranging from hundreds of thousands of US dollars to roughly over a billion dollars to acquire the system (Zeng, Lu, & Skibniewski, 2012).

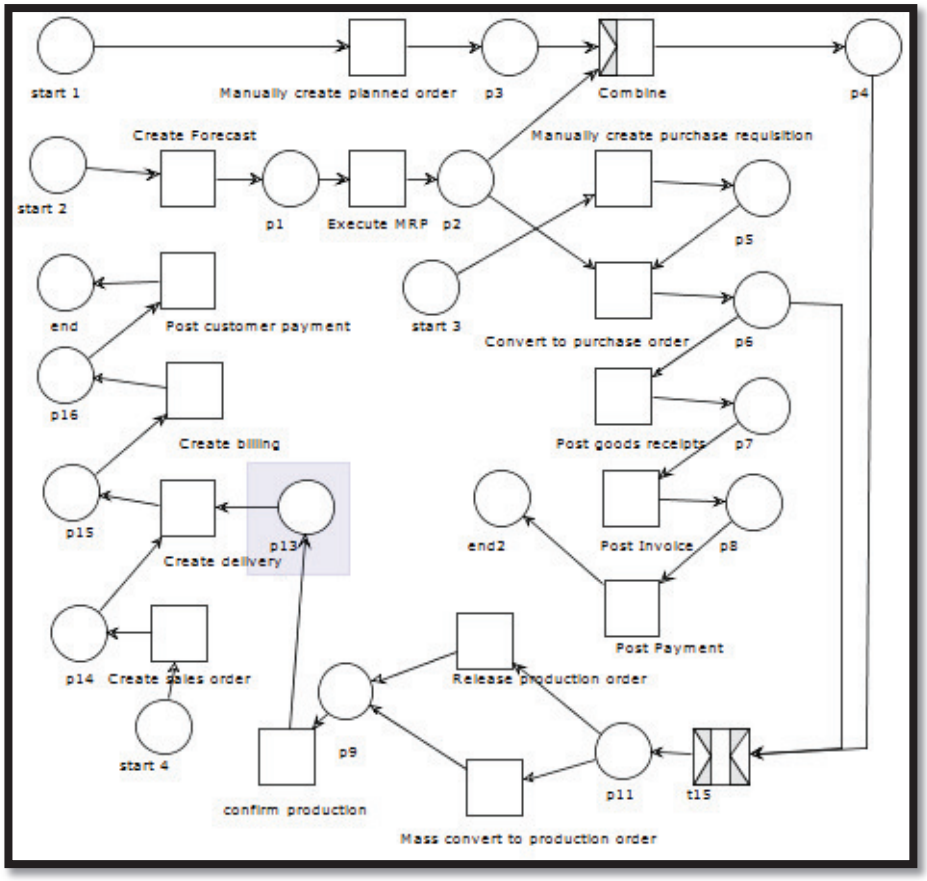


Figure 1.1.1 Macro Production BP of Company XYZ drew by WoPed

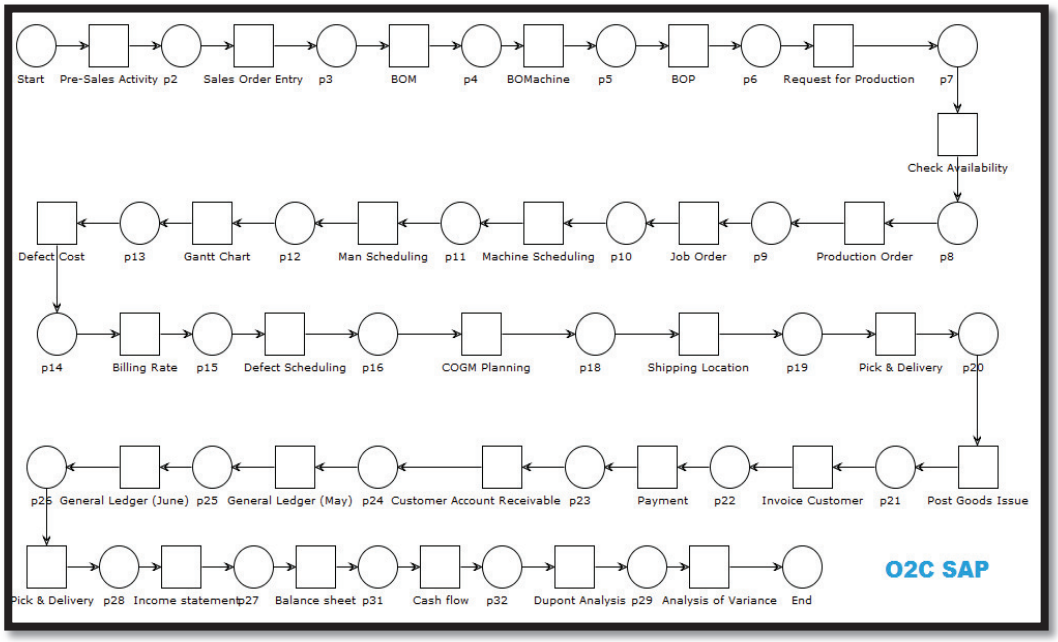


Figure 1.1.2 Business' expected ERP modules for order to cash activity (Catt, 2008)

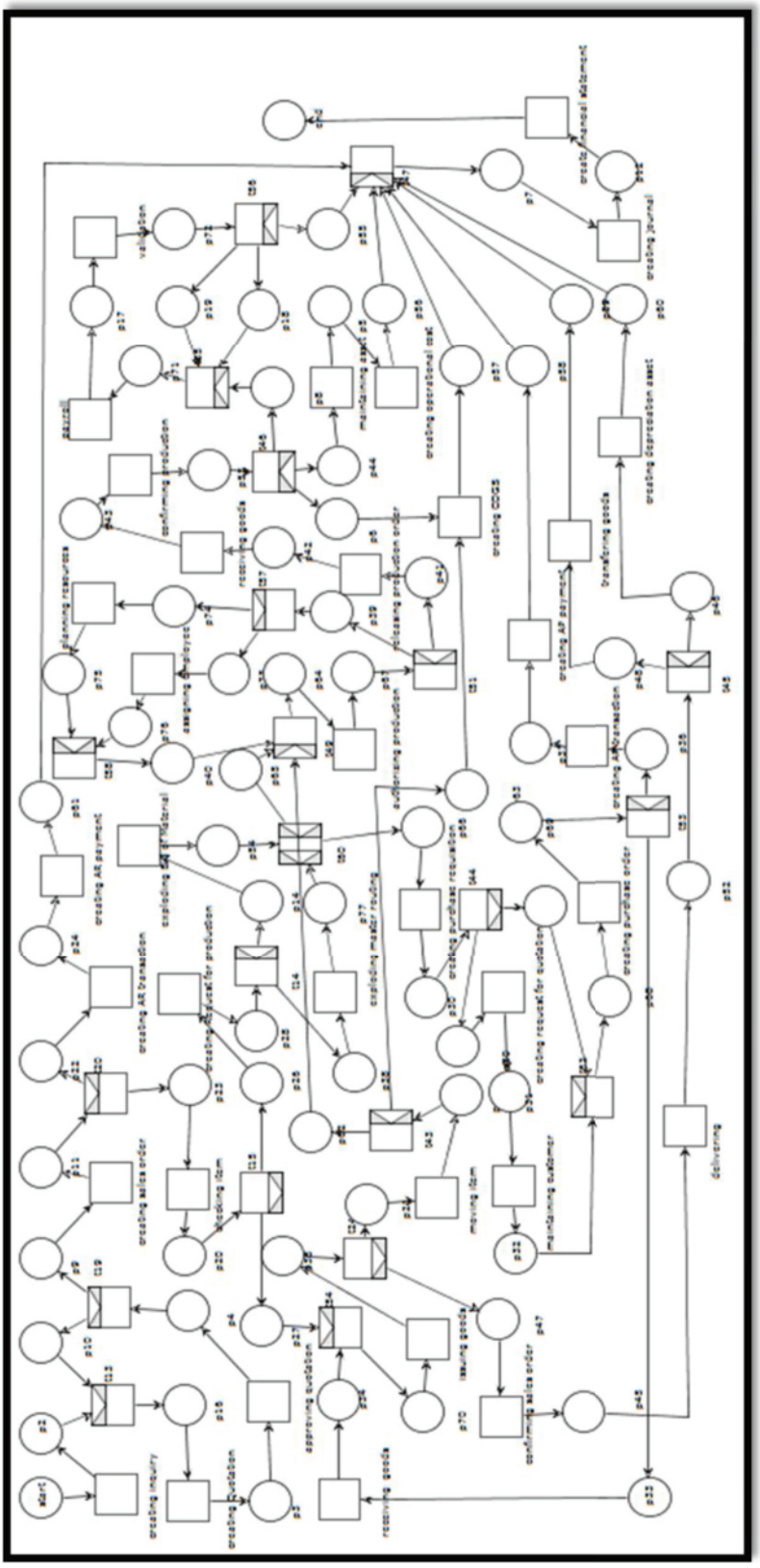


Figure 1.1.3 Make to Order Requirement

Adopting the open-source ERP become one of the viable solution. The advantage of this approach is most cost will be allocated in installation and customization. There are several open-source ERP system to choose which are InoERP, Odoo, and Adampiere. The project management team need to select a system that can be easily customized which will affect the time and cost invested without neglecting the business value expected by the client.

The team will need to select ERP system with the least scope of customization work with several tools. Customization is needed to fulfill the *business requirement* which is close to the framework of *extended ERP* of SAP for manufacturing. In order to achieve the *goal*, a *Fuzzy Multi-criteria decision making* (MCDM) will be utilized as a selection method. *Fuzzy scale* is also used to quantify the qualitative value of the study. MCDM is the recent popular method of selection after scoring and ranking methods, and mathematical optimization models (Kilic, Zaim, & Delen, 2014). The *fuzzy sets* will increase the accuracy of the variables' weight from the expert. The criteria used for *pair-wise comparison* will follow the recent guidelines *International Organization for Standardization* (ISO) 25022 and collaborate it with COCOMO *II* cost driver parameters with the ISO economic or financial measures.

The expected result from this study is selection of a suitable ERP system for the company XYZ which has the least scope of customization work and fit with the BP. The finding will be confirmed by the expert to ensure that customization complexity will take the least time and more precise than the previous method that does not integrate COCOMO II into the measurement.

1.2 Formulating the problem

Based on the background, formulated problems are as follow:

1. How to select the appropriate ERP system that meet the business requirements based on the functional and financial criteria of ISO 25022?
2. How to measure the scope of work for customization by measuring business process gap?
3. How to optimize ERP selection based on several expert preferences?

4. How to increase the criteria relavancy to achieve the intended cost benefit through combining ISO 25022 with COCOMO II cost drivers?

1.3 Purpose of the research

The purposes of this study of ERP selection method are:

1. Selecting the right system will increase the likelihood of successful ERP implementation at company XYZ. The study is expected to develop a method for selecting a system that is suitable for the business. It is expected the selected system has the same rank as the fuzzy set method.
2. Integrate business similarity as inputs to COCOMO II four cost drivers and other four criteria
3. Select method that is simple and eliminate ambiguity of the expert evaluation.
4. Combining one of the criteria financial measures of the ISO/IEC 25022 criteria with COCOMO II will be able to give a better result of selection and more precise estimation of cost.

1.4 Benefit of the research

The benefit of this procurement planning for company XYZ are:

1. ERP system will be effective and effecient. Less scope of customization should provide adequate time to meet all the business requirement and for testing. Effective ERP will give the competitive advantage that the company expected.
2. Minimizing the cost of ERP extended acquisition through open-source software and ability to deliver comparable quality to SAP ERP can be beneficial for small-medium companies especially the one in third world country.
3. Anticipating the selected system has the least customization work with a maximum *Return of Investment* (ROI).

1.5 Contribution of this research

The expected result of this non-probability study are:

1. Business process gap will estimate the scope of work for customization. The expert will confirm the least customization is also the least cost of customization.
2. Cost of customization using COCOMO II
3. Selection process can be shortened by evaluating the BP similarity. The expert will confirm if the measurements combination have improve the accuracy of study.

1.6 Scope of the study

The limitations or scope of this study are:

1. All selected ERP softwares are Open-source and web based.
2. Business system requirements for business are given and match the industry leader.
3. Fundamental *Business Process* represent most of the activities are true.
4. Assumed that all variables from ISO 25022 and COCOMO II are validated. Only the functional and financial variable.
5. The relation between variables how it is influence each others is not within this research.
6. Assumed that the business' BP is fit for ERP as they already follow the best practice SAP. *Business Process Reengineering* (BPR) and *Business Process Management* (BPM) are not needed.
7. Production business process will be prioritized for similarity. Specifically, the make to order process.
8. Business Process used only on level 1. Deeper activities on level 2 and 3 are not within the research scope. Complexity is not within the research.
9. Integration measurement scale for Similarity and COCOMO II distributed equally. Further adjustment can be done on future research.

10. As for COCOMO II, the worker are set at minimum wage $2000 per person per month and the maintenance is not counted. This is done for the purposed of controlled environment as the research should minimized any variables.
11. BP similarity best method is not within the research.

The research is divided into several phases which begin by finding the BP gap to support the six critical cost drivers which currently rely heavily on expert. Findings gap will be achieved through calculating the similarity of the alternatives systems and the BP requirement. The other eleven cost drivers will be using fuzzy scale. The outputs will be used as input to estimate the cost of reconstruction. This method will be validated by testing on the turnkey dataset provided. This is the major contribution of this research.

1.7 Writing structure

Chapter I background of the thesis which briefly describe the role of ERP, relation to project management (PM), importance of system selection, business requirement, usage of open-source justification, proposed method, and expected result. It is explaining the current issue of ERP implementation and the main risk factor that need to be solved.

Chapter II is literature review, which become the foundation of the study. It is describing the specific jargons definition. The concept of ERP implementation, selecting, how to measure, the scale that will be used, the ISO that is adopted, and also measurement of the specific variable. The focus on increasing the precision of the variable measurement is the main discussion in this study.

Chapter III explaining about how the research will be conducted. It will describe the expected output of every phase within the research. Output may be revised as the research examine further.

CHAPTER II
LITERATURE REVIEW

Operational definition elaborate the details of jargons used in the study of ERP selection based on International standard and Industry standard. Definition is needed to help further understanding of the problem which also mentioned in the background. It is also emphasized the contribution of this study. The definitions will be mentioned throughout the study report.

2.1 Company XYZ

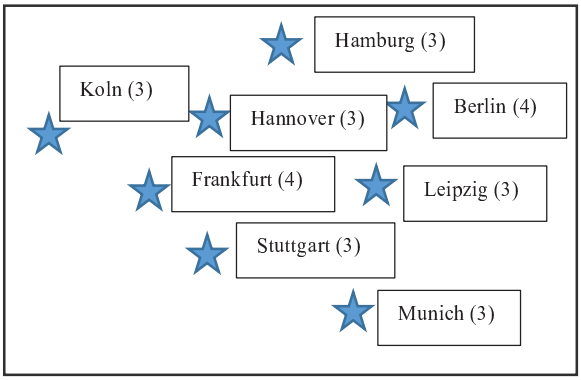


Figure 2.1.1 Distribution locations of Company XYZ in German

The cereal manufacturing operate in German and distribute in 26 cities as *Figure 2.1.1*. Known for the six products with varies of composition of wheat, oat, nut, strawberry, berry, and dried raisin which packaged into 500 gram or 1 kg. The company always stock raw materials for 100,000 boxes and has the production capacity of 25,000 boxes per day. Most of the activities is a make to stock process. The business need to focus on efficiency as their current system is effective. It is assumed that total cost of production is $5,000,000.

This ERP selection project focus on the matching of the production process only. Accounting become the center of all department process as in *Figure 2.1.2*. The system focuses on integration of all information from different departments. Automation of the business process allow to reduce in communication lag and inaccuracy. Further research focus on the accuracy of forecasting. However, forecasting is not within the scope of this research.

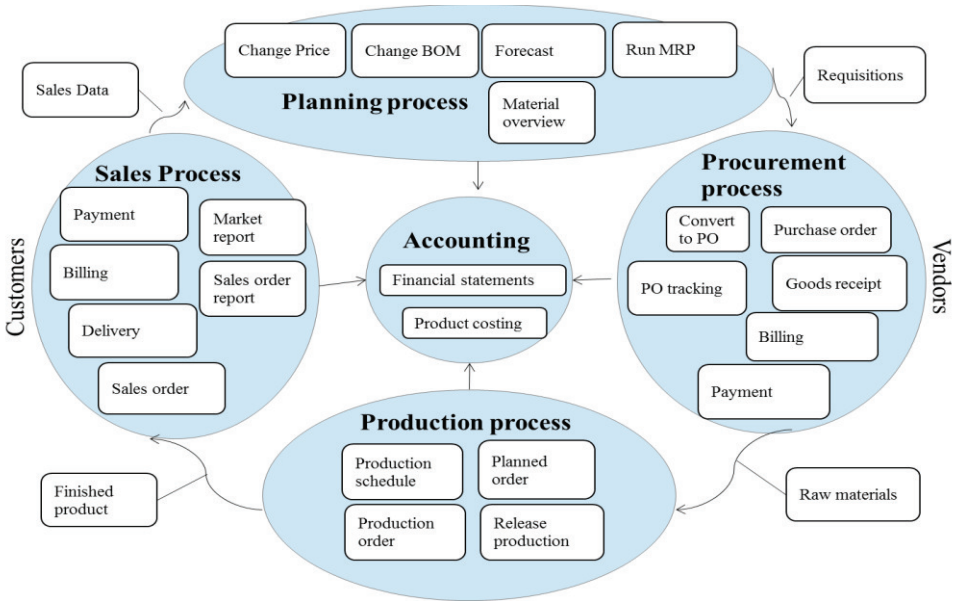


Figure 2.1.2 The expected ERP workflow in company XYZ after implementation

2.2 Extended Enterprise Resource Planning

ERP has went through evolution since the 60's as Material Requirement Planning (MRP) until known as the extended ERP or ERP II in the 21st century. Gartner group claimed to found the new concept of ERP II, integrating inter-organizational to increase collaboration effectiveness and business efficiency (Accountancy, 2001).

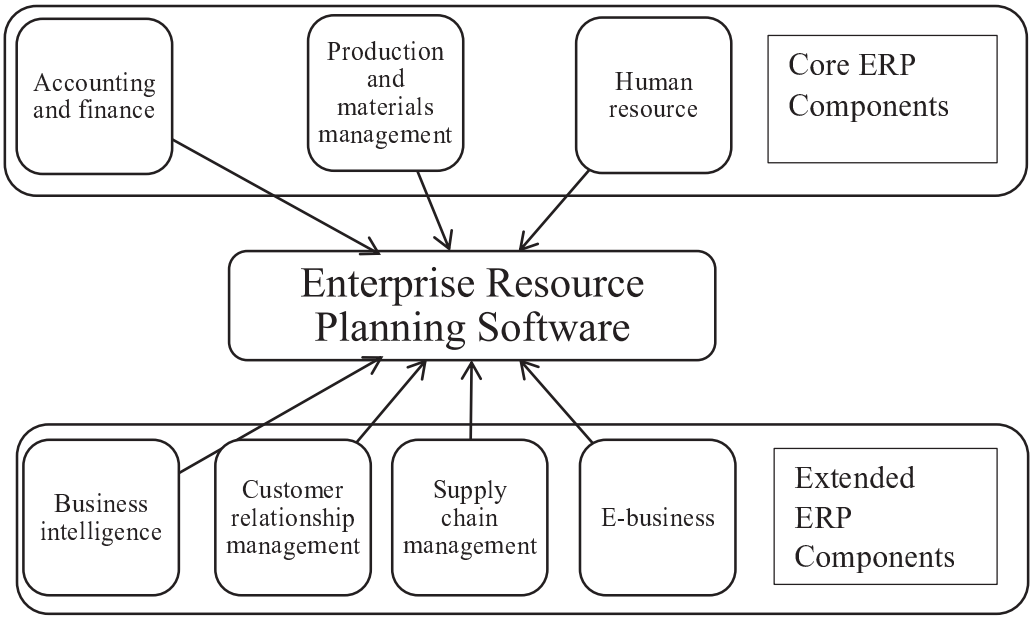


Figure 2.2.1 Extended ERP components

2.2.1 Benefits of ERP

The company XYZ current operational cost is about $5 million. The known benefit adopting ERP system are increasing productivity, reduced operating costs and ultimately increase profit (Magal & Word, 2012). This will be useful to calculate payback period of the ERP system.

Table 2.2.1 Benefit of integrated system such as ERP

Benefit	Saving
Cost reduction	2-5%
Productivity	10-15%
Resource utilization	10-20%
Stock reduction	25-50%
Throughput time	10-20%
Delivery reliability	5-10%
Planning accuracy	25-80%

Source: (ATOS, 2012)

The assumption, the success of ERP implementation to company XYZ is 2% of the current cost of operation. It is about $100,000 to be saved from current monthly operational cost and other intangible benefit will tagged along as well.

2.2.2 Branded ERP

There are lots of ERP out there from the well-known brand to the open source. The cost usually charged based on license, number of user, add-in, and implementation cost. It is start from $150,000 to $1,000,000 depending on the business needs. This research try to use SAP as a benchmark to see how much customization will be needed to achieve the same function as the best ERP in the market.

Table 2.2.2 ERP top 5 vendor in manufacturing and distribution

No.	Company	Market share
1	SAP	35
2	Oracle	23
3	Microsoft	15
4	Infor	4
5	Epicor	2

Source: (ATOS, 2012)

2.2.3 Open Source ERP system

Open source software means the source code of the software is available to the general public to access (Laurent, 2004). It was discovered not all open-source ERP was easily accessed. Only few that are available and have a high number contributors into the systems, they are:

1. InoERP - Mozilla Public License published by Mozilla Foundation (inoERP, 2015).
2. Odoo - GNU Lesser General Public License (LGPL) published by Free Software Foundation (Odoo S.A, 2015).
3. Adempiere - GNU Lesser General Public License (LGPL) published by Free Software Foundation (ADempiere, 2015).

2.3 ISO/IEC 25022

The standards context are explaining how to apply software and system quality measures, a set of quality measures characteristic, and further example of how to apply it during the product life cycle (ISO/IEC, 2012). This is intentionally designed for procurement.

ISO 25022 most recent measurement of quality in use standard for software and system quality. ISO 25022 is a part of System and software Quality Requirements and Evaluation (SQuaRE) that focuse more how to measure the subcharacteristics in use model (ISO/IEC, 2012). The focus of this study integrating the financial measures mentioned in *Table 2.3.1*. All the main focuses are bolded.

There are specific terms used repeatedly in this standard, such as:

a) Effectiveness – completeness to achieve user specified goals
b) Efficiency – relation to the accuracy and completeness
c) Goal – expected or desirable outcome
d) Measure – value which assign and produce a measurement
e) Quality measure – measurement functions of two or more quality measure elements
f) Quality measure element – attribute method for quantifying
g) Satisfaction – User's response to the product or system
h) Task – physical or cognitive activities to reach goal

Table 2.3.1 Characteristics of in use model for SQuaRE

Effectiveness measures	**Effectiveness measures**	**Task completion**
		Task effectiveness
		Error frequency
Efficiency measures	**Efficiency measures**	Time efficiency
		Relative task time
		Task efficiency
		Relative task efficiency
		Economic productivity
		Productive proportion
		Relative number of user actions
Satisfaction measures	**Usefulness measures**	**Satisfaction scale**
		Satisfaction questionnaire
		Discretionary usage
		Discretionary utilization of functions
		Proportion of Customer complaints
	Trust measures	Trust scale
	Pleasure measures	Pleasure scale
	Comfort measures	Comfort scale
Freedom from risk measures	Risk mitigation measures	Risk mitigation
	Financial measures	***Return of investment (ROI)***
		Time to achieve a return of investment
		Relative business performance
		Balance Score Card
		Delivery time
		Missing items
		Revenue for each customer
		Errors with economic consequences
		Software corruption
	Health and safety measures	User health and safety frequency
		User health and safety impact
		Safety of people affected by use of the system
	Environmental measures	Environmental impact
Context coverage measures	Context completeness measures	**Complex completeness**
	Flexibility measures	Flexible context of use
		Flexible design features

2.4 COCOMO II

COCOMO II is a cost estimation model for software development. Developed by Barry W. Boehm, using basic regression formula from historical, present and future project data or characteristic (Boehm, 2000). COCOMO II cannot be used alone for ERP selection. It gives inadequate variable in the aspect of matching the business process between actual and the expected.

The cost drivers will be imbedded into the ISO/IEC 25022 measures to decrease uncertainty for open-source ERP selection. It will make the selection method more precise by making the economic variable from ISO sensitive to the customization cost.

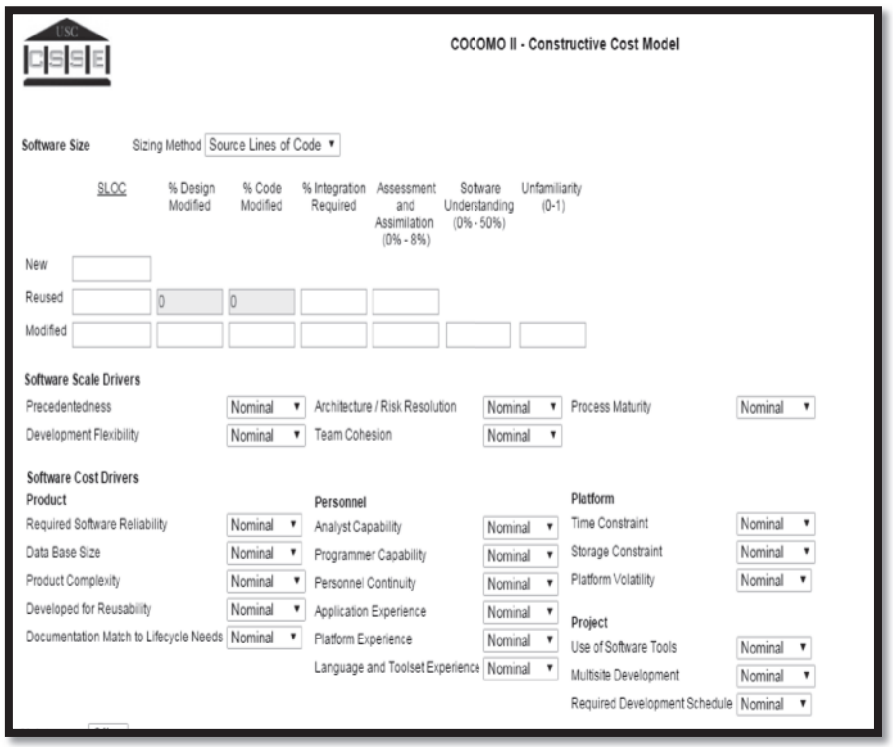


Figure 2.4.1 COCOMO II interface (Madachy, 2015)

COCOMO II variables use qualitative scale still. There is an opportunity to use arithmetic scale in the future to increase accuracy. This field strongly rely on the experts' judgments like consultant or the project

manager. Selecting the four expert for this research will be based on their experience in IT, have used the open-source ERPs, and experience in using COCOMO II.

Common formulas used in COCOMO II are:

$$\mathbb{E} = \mathbb{B} + 0.01 \sum SF$$

Equation 2.4.1 Project size exponential formula

$$\mathbb{PM} = \mathbb{A} \times (KLOC)^{\mathbb{E}} \times \prod_{\mathbb{i}=1}^{\mathbb{m}} EM_1$$

Equation 2.4.2 Person-Month Effort estimation formula

$$Cost = \mathbb{PM} \times salary\ person\ per\ month$$

Equation 2.4.3 Cost of construction formula

Legends:

$\prod_{\mathbb{i}=1}^{\mathbb{m}} EM_1 = multiply\ all\ effort\ multiplier$

$KLOC = Source\ Line\ of\ Codes \div 1000$

$\mathbb{A} = 2.94$

$\mathbb{B} = 0.94$

$\sum SF = sum\ of\ all\ scale\ factors$

The formulas inputs are the 17 cost drivers and the 4 scale factors. *Table 2.4.1 Constructive Cost Model cost drivers* explains how the 17 cost driver categorized and *Table 2.4.2* explain further about what each cost driver means. *Table 2.4.3* is the scale factors value for precedent, development flexibility, risk

resolution, team solidity, and process maturity level. They can be set to default as this experiment which is set to nominal.

Table 2.4.1 Constructive Cost Model cost drivers

Product Factors	*RELY- Required Software Reliability*
	DATA - Data Base Size
	CPLX - Product Complexity
	RUSE - Required Reusability
	DOCU - Documentation match to life-cycle needs
Platform Factors	*TIME - Execution Time Constraint*
	STOR - Main Storage Constraint
	PVOL - Platform Volatility
Personnel Factors	*ACAP - Analyst Capability*
	PCAP - Programmer Capability
	AEXP - Applications Experience
	PEXP - Platform Experience
	LTEX - Language and Tool Experience
	PCON - Personnel Continuity
Project Factors	*TOOL - Use of Software Tools*
	SITE - Multisite Development
	SCED - Required Development Schedule

Table 2.4.2 Cost Drivers interpretation

No.	Cost Driver	Concern
1	**RELY**	The effect of software failure
2	**DATA**	Data scope needed
3	**CPLX**	The level of complexity of a software
4	**RUSE**	The SLOC reusability
5	**DOCU**	documentation fitness to the needs
6	**TIME**	the speed of system execution
7	**STOR**	Data storage needed
8	**PVOL**	Changes of software towards complexity
9	**ACAP**	capability of the analyst
10	**PCAP**	Programmers capability at teamwork
11	**PCON**	Employee changes in a year
12	**APEX**	Experience of developer
13	**PLEX**	Experience of developer in using the platform to build database
14	**LTEX**	Experience of developer in programming language
15	**TOOL**	Tools used to build
16	**SITE**	Data distribution reach
17	**SCED**	The speed of development to the given time

Table 2.4.3 Scale Factors Values for COCOMO II

Scale Factors	Very Low	Low	Nominal	High	Very High	Extra High
PREC SF1:	Thoroughly unprecedented 6.20	Largely unprecedented 4.96	Somewhat unprecedented 3.72	Generally familiar 2.48	Largely familiar 1.24	Thoroughly familiar 0.00
FLEX SF1:	Rigorous 5.07	Occasional relaxation 4.05	Somewhat relaxation 3.04	Generally conformity 2.03	Somewhat conformity 1.01	General goals 0.00
RESL SF1:	Little (20%) 7.07	Some (40%) 5.65	Often (60%) 4.24	Generally (75%) 2.83	Mostly (90%) 1.41	Full (100%) 0.00
TEAM SF1:	Very difficult interactions 5.48	Some difficult interactions 4.38	Basically cooperative interactions 3.29	Largely cooperative 2.19	Highly cooperative 1.10	Seamless interactions 0.00
PMAT SF1:	SW-CMM Level 1 Lower 7.80	SW-CMM Level 1 Upper 6.24	SW-CMM Level 2 4.68	SW-CMM Level 3 3.12	SW-CMM Level 4 1.56	SW-CMM Level 5 0.00

Table 2.4.4 Component Complexity Level

	Control Operations	Computa-tional Operations	Device-dependent Operations	Data Management Operations	User Interface Management Operations
Very low	Straight-line code with a few non-nested structured programming operations: DOS, CASEs, IF-THEN-ELSEs. Simple module composition via procedure call or simple scripts	Evaluation of simple expressions e.g. A+B+C*(D-E)	Simple read, write statements with simple formats.	Simple arrays in main memory. Simple COTS-DB queries, updates	Simple input forms, report generators.
Low	Straightforward nesting of structured programming operators. Mostly simple predicates	Evaluation of moderate-level expressions e.g. D=SQRT(B **2-4.*A*C)	No cognizance needed of particular processor or I/O device characteristics I/O done at GET/PUT level	Single file sub-setting with no data structure changes, no edits, no intermediate files. Moderately complex COTS_DB queries updates	Use of simple graphic user interface (GUI) builders.
Nominal	Mostly simple nesting. Some intermodule control. Decision tables. Simple callbacks or message passing, including, middleware-supported distributed processing	Use of standard math and statistic routines. Basic matrix/vecto r operations.	I/O processing includes device selection, status checking and error processing.	Multi-file input and single file output. Simple structural changes, simple edits. Complex COTS-DB queries, updates.	Simple use of widget set.

Table 2.4.5 Component Complexity Level continued

	Control Operations	Computational Operations	Device-dependent Operations	Data Management Operations	User Interface Management Operations
High	Highly nested structured programming operations with many compound predicates. Queue and stack control. Homogeneous, distributed processing. Single processor soft real-time control	Basic numerical analysis: multivariate interpolation, ordinary differential equations. Basic truncation, round-off concerns.	Operations at physical I/O level (physical storage address translations; seeks, reads, etc.). Optimized I/O overlap.	Simple triggers activated by data stream contents. Complex data restructuring.	Widget set development and extension. Simple voice I/O multimedia
Very High	Re-entrant and recursive coding. Fixed-priority interrupt handling. Task synchronization, complex callbacks, heterogeneous distributed processing. Single processor hard real-time control.	Difficult but structured numerical analysis: near-singular matrix equations, partial differential equations. Simple parallelization	Routines for interrupt diagnosis, servicing masking. Communication line handling. Performance-intensic embedded systems.	Distributed database coordination. Complex triggers. Search optimization.	Moderately complex 2D/3D dynamic graphics, multimedia.
Extra High	Multiple resource scheduling with dynamically changing priorities. Microcode-level control. Distributed hard real-time control.	Difficult and unstructured numerical analysis: highly accurate analysis of noisy, stochastic data. Complex parallelization.	Device timing-dependent coding, micro-programmed operations. Performance-critical embedded systems.	Highly coupled dynamic relational and object structures. Natural language data management.	Complex multimedia, virtual reality, natural language interface.

For this ERP system project, the system development is Extra high based on Table 2.4.4. Other cost drivers are explain below on Table 2.4.6. It will be converted to nominal with Table 2.4.7. All of this information is available on the COCOMO II guidelines. The accuracy of the COCOMO II has been tested numerous times by other scholars. Some still improving its accuracy in cost estimation. However, it is not the focus of this research. This research goal simply to integrate COCOMO II and still get the same highest rank system as another method.

Table 2.4.6 Cost drivers rating level

No.	Cost Driver	Very Low	Low	Nominal	High	Very High	Extra High
1	RELY	Slightly Inconvenience	low, easily recoverable losses	moderate, easily recoverable losses	high financial loss	risk to human life	-
2	DATA	-	SLOC<10	10=SLOC< 100	100=SLOC<1000	SLOC = 1000	-
3	CPLX	-	-	-	-	-	-
4	RUSE	-	none	across project	across program	across product line	across multiple product lines
5	DOCU	many life cycle needs uncovered	some lifecycle needs uncovered	right size to life cycle needs	excessive for life cycle needs	very excessive for life cycle needs	-
6	TIME	-	-	50% use	70% use	85% use	99% use
7	STOR	-	-	50% use	70% use	85% use	99% use
8	PVOL	-	Major = 12 Month, Minor 1 Mont	Major = 6 Month, Minor = 2 Week	Major = 2 Month, Minor = 1 week	Major = 2 week, Minor = 2 days	-
9	ACAP	15%	35%	55%	75%	90%	-
10	PCAP	15%	35%	55%	75%	90%	-
11	PCON	48%/year	24%/year	12%/year	6%/year	3%/year	-
12	APEX	<=2month	6month	1 year	3 year	6 year	-
13	PLEX	<=2month	6month	1 year	3 year	6 year	-
14	LTEX	<=2month	6month	1 year	3 year	6 year	-
15	TOOL	edit, code, debug	simple, frontend, backend, case, little integration	basic life-cycle tools, moderately integrated	strong, mature life cycle tools, moderate integrated	strong, mature, proactive life-cycle tools, well integrated with processes methods, reuse	-
16	SITE	international	multi-city and multicompany	multi-city or multicompany	same city or metro area	same building or complex	fully alocated
17	SCED	75% of Nominal	85% of nominal	100% of nominal	130% of nominal	160% of nominal	-

Table 2.4.7 Effort multiplier descriptor

Descriptor to convert rating levels of each cost drivers to Effort multiplier						
COST DRIVERS	**Very Low**	**Low**	**Nominal**	**High**	**Very High**	**Extra High**
RELY	0.82	0.92	1.00	1.10	1.26	n/a
DATA	n/a	0.90	1.00	1.14	1.28	n/a
CPLX	0.73	0.87	1	1.17	1.34	1.74
RUSE	n/a	0.95	1.00	1.07	1.15	1.24
DOCU	0.81	0.91	1.00	1.11	1.23	n/a
TIME	n/a	n/a	1.00	1.11	1.29	1.63
STOR	n/a	n/a	1	1.05	1.17	1.46
PVOL	n/a	0.87	1	1.15	1.3	n/a
ACAP	1.42	1.19	1	0.85	0.71	n/a
PCAP	1.34	1.15	1	0.88	0.76	n/a
PCON	1.29	1.12	1	0.9	0.81	
APEX	1.22	1.1	1	0.88	0.81	n/a
PLEX	1.19	1.09	1	0.91	0.85	n/a
LTEX	1.2	1.09	1	0.91	0.84	
TOOL	1.17	1.09	1	0.9	0.78	n/a
SITE	1.22	1.09	1	0.93	0.86	0.8
SCED	1.43	1.14	1	1	1	n/a

2.5 Project Management

Project manager (PM) and its team will be appointed by the top management to conduct the selection process (Pitic, Popescu, & Pitic, 2014). The team will apply their knowledge, related skill, variety of tools and different techniques to the project to meet the business requirement (PMI Inc., 2013).

2.5.1 Project Management Body of Knowledges

IT Project management body of knowledge (PMBOK) is similar to the regular PMBOK. It contains the ten body of knowledge for IT project management. Figure 2.9.1 shows that project manager and the team will be needed for the system selection project. This project is classified as part of

procurement management. Within the procurement project a certain quality is set with the goal to maintain the lowest cost.

Table 2.5.1 The ten Project Management Body of Knowledge

Integration Management
Scope Management
Time Management
Quality Management
Cost Management
Human resource (HR) Management
Communications Management
Risk Management
Procurement Management
Stakeholder Management

Source: (PMI Inc., 2013)

2.5.2 Procurement Management

Procurement management defined as a collection of several processes to obtain tangible or intangible goods or services (PMI Inc., 2013). In this study would be the ERP system and the necessary installation equipment to allow customization.

2.6 Business Process

Business process is a collection of linked task in a business. Every activity has different linkages (Magal & Word, 2012).

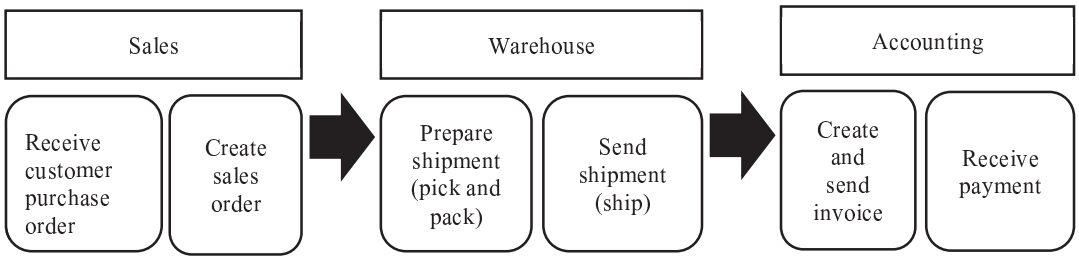


Figure 2.6.1 Order to cash business process (Magal & Word, 2012)

Figure 2.6.1 Order to cash business process of businesses are varies depending on their Standard Operating Procedure (SOP). Sometimes Business Process Management (BPM) or Business Process Re-engineering (BPR) will be needed to fit the modules of actual to expectation.

Business process sometimes change as the business activity becomes more complex due to expansion or new SOP. To intentionally change BP also known as BPR. It is necessary to evaluate the BP before selecting the ERP system. The gap between the actual BP and expectation will also reflect the need of the business requirement. BPR usually is necessary when the BP of the firm is not effective or have leakage that can affect their profitability. Project Management team must evaluate that all BP activity are covered in the ERP system modules. Despite all, sometimes BPM is enough if the firm only need an optimization to increase their workflow efficiency.

An ERP functionality effectiveness rely on the module coverage completeness. *Figure 2.6.2* shows a complete BP activities that effect business decision for procurement or known as MRP which was explained previously.

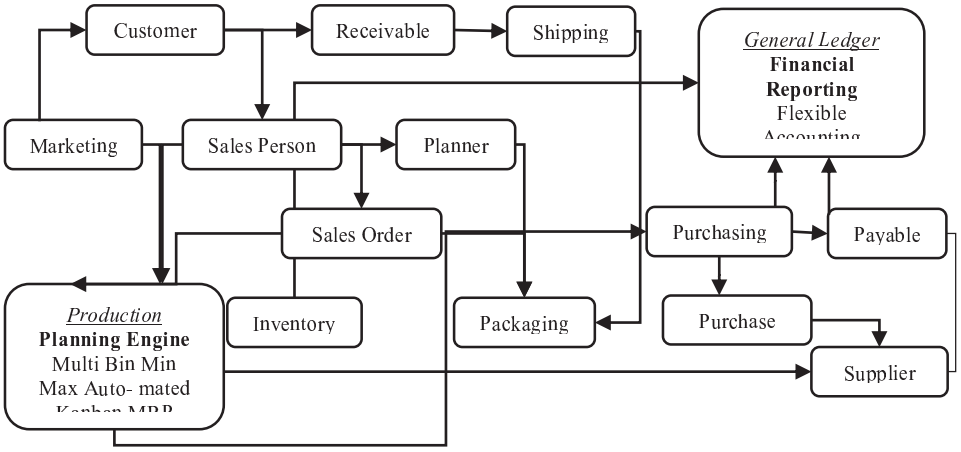


Figure 2.6.2 Macro view of business process from inoERP (inoERP, 2015)

2.6.1 Business Process drawing tools

BP similarity measure the distance or degree of similarity between two different business processes. At this study will be compare between the

system ERP BP to the business' BP. Measuring the distance or the gap of difference enable developer to estimate the scope, time, and cost of customization (Bae, 2006). The ultimate intention of fitting functionality is increasing the likelihood of ERP successfulness.

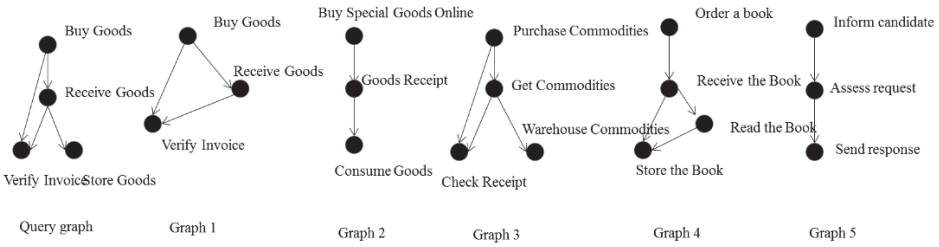


Figure 2.6.3 Example of comparing different BP in graphs (Bae, 2006)

There are several of methods to calculate the similarity of BP similarity. The most used is comparison by experts. Several study mentioned that there are several challenges faced during the comparison such as labeling terminology and how businesses do not have a clear mapping of their business activities. In order to help the experts making evaluation for this paper a Business Process Modelling Network (BPMN) software will be used. The BP in BPMN graph forms as in *Figure 2.6.4*. It is easier to understand.

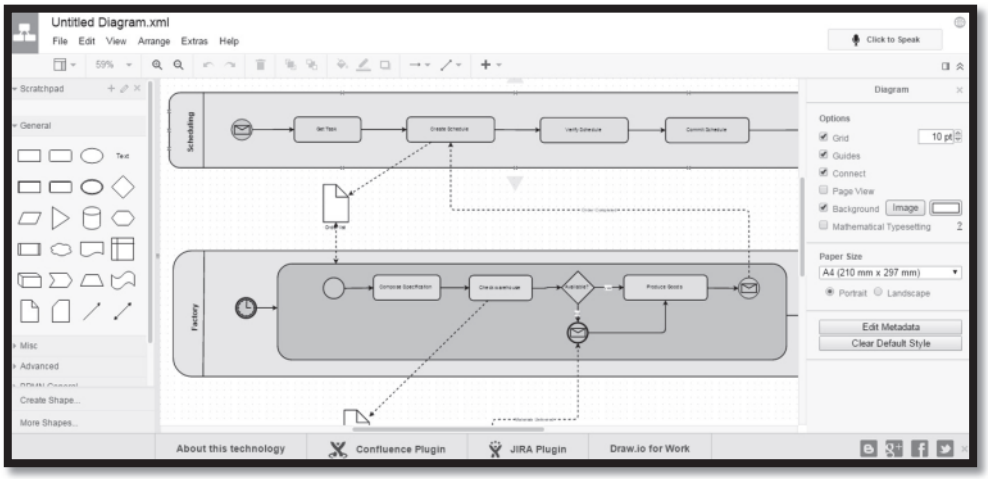


Figure 2.6.4 BPMN software from draw.io to draw graph

PNML is chosen because its flexibility to be used for atomization or quantitative programs like beehivez. Beehivez is a program for calculating business process similarity. The BP will be drawn with WoPed, an open source software. Only the workflow will be drawn without the event logs. Figure 2.6.5 shows the interface of the program. The drawings will be saved in PNML files as an input for BP similarity calculation.

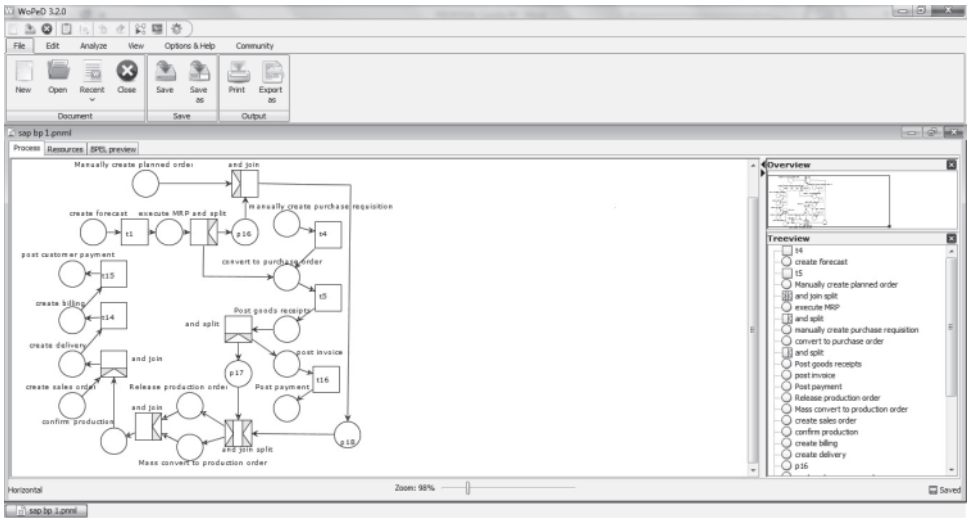


Figure 2.6.5 WoPed software interface

2.6.2 Business Process Similarity

Workflow in PNML files will be used definitely for structure and behavior BP similarity. There are possibility for using beehivez for textual similarity as well. The figure below shows the diagram of BP similarity tools and methods. Once again, the accuracy of BP similarity is not the aim of the paper. It focuses on how the BP similarity can be used as an input to replace the expert evaluation on the systems.

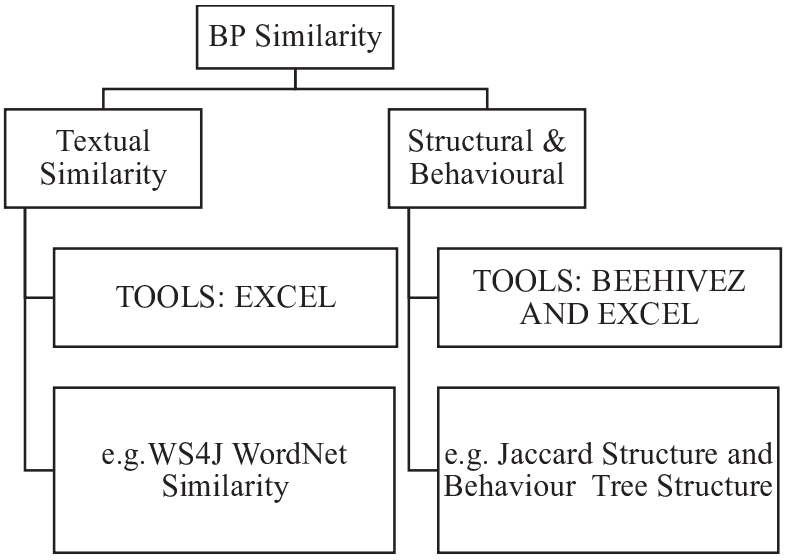


Figure 2.6.6 Example of BP Similarity

The method of calculating the similarity will be kept as simple as possible. It is still remain uncertain which methods were the best. The paper will not focus on the similarity accuracy. However the accuracy of the calculation is recognized as variable that effect the selection. Business Process Similarity divided into textual, structural, and behavioural (Humm Fengel, n.d).

a. Textual or Semantic

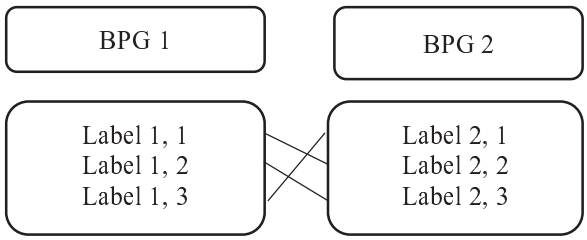


Figure 2.6.7 Node similarity (Remco Dijkman, Dumas, 2011)

The synonym research is not within the research. It is relying on WS4J which connected to the WordNet. It is an English database

grouped by synonym (Shima, 2016). Below, are examples of the result of WS4J.

Table 2.6.1 Textual synonym example

6		d1	d2
d1	receive	1	1
	good	1	1
d2	receive	1	1
	good	1	1

5		d1	d2
d1	receive	1	1
	good	1	0.7692
d2	receive	1	1
	item	0.7692	1

Then, it will be calculated for requirements textual similarity to all the alternatives with the similarity cosine.

$$Sim\,(d1, d2) = \frac{d1 \times d2}{\|d1\|\|d2\|} = \frac{\sum_{i=1}^{n} d1_i\, d2_i}{\sqrt{\sum_{i=1}^{n} d1_i^2}\ \sqrt{\sum_{i=1}^{n} d2_i^2}}$$

d1 = document 1 Vector Synonym

d2 = document 2 Vector Synonym

Equation 2.6.1 Cosine Similarity for textual

b. Structural

In Beehivez program a model in PNML file will be uploaded. Structures between both will be calculated. For example on *Table 2.6.2* Model B is different from Model A, and D. However, the formula will not be able to detect the difference in behaviour like comparison of model C to model B. This is where behavioural similarity fill in the lackness of structural similarity. It does not detect the XOR or AND behaviour in PNML.

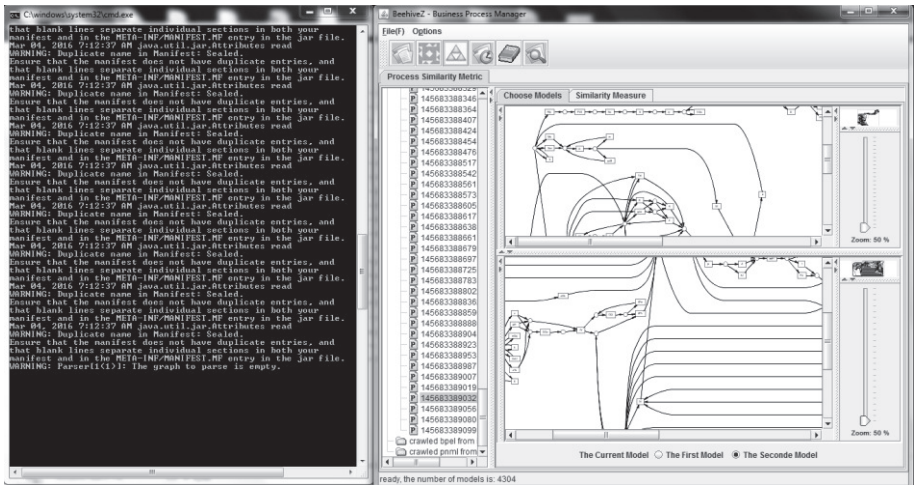


Figure 2.6.8 Beehivez Workflow Similarity Tool

An example of structural similarity is Jaccard structure Similarity.

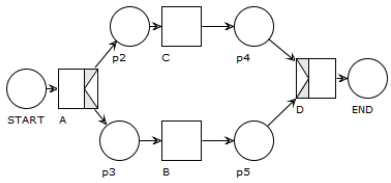
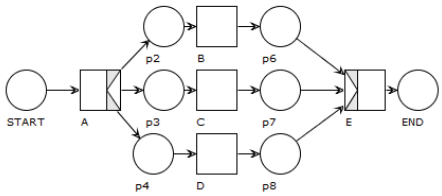
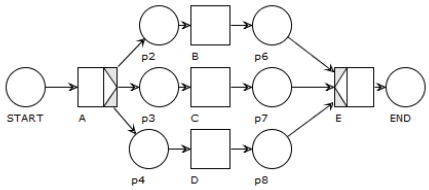
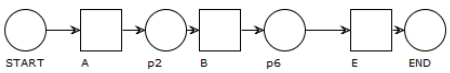
$$JS(A,B) = \frac{|\sum L\,A \cap \sum L\,B|}{|\sum L\,A \cup \sum L\,B|}$$

LA = Total label A

LB = Total label B

Equation 2.6.2 Jaccard similarity

Table 2.6.2 Example of Jaccard Structure PNML models

MODEL	GRAPHS	CHARACTERISTIC
A		AND SPLIT 2
B		AND SPLIT 3
C		XOR SPLIT-JOIN
D		SEQUENTIAL

c. Behavioural

One of the behavioral similarity is Behavioural Tree Structure which can be calculated with Beehivez. It can also embedded into the structure similarity calculation.

Table 2.6.3 Behavioural Tree Structure Similarity example Req vs ino

First Coverability Tree Petri Net 1	Second Coverability Tree Petri Net 2
(0:[0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,1,0,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0]) (1:[0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,0,1,0,0,0,0,0, 0,0,0,0,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0])	(0:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,1,0,0,0,0,0,0,0,0,0]) (1:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0]) (2:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0]) (3:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (4:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1, 0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (5:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (7:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (10:[0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (14:[0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0, 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (11:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (15:[0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (8:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (12:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (16:[0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (6:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (9:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (13:[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0, 0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]) (17:[0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0])

The similar vector of these two petri net is :{ 0.05, 0.05, 0.05, 0.05, and 0.125}

The similarity coefficient of these two petri nets is: 0.30

2.7 Business Requirement

Selecting the right system can increase the implementation success and either avoid or mitigate the negative outcome. Company XYZ requirement is as shown in *Figure 1.1.1*. Many research attempt to improve the selection method to meet the business requirements. The risk can be mitigate by improvise the selection method to reduce the time of customization, cost to fit into the requirements of business, and scope of technical work to meet specific quality standard. Business requirement goals for the ERP selection project:

a) Scope – expectation (Less)
b) Time – expectation (Quicker)
c) Cost – expectation (Cheaper)
d) Quality – expectation (Consistent)

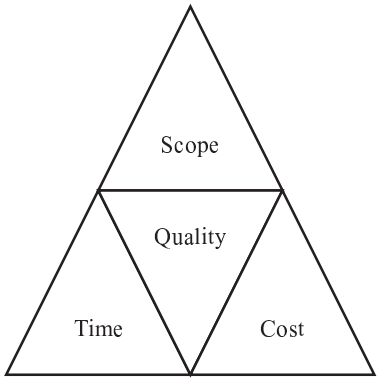


Figure 2.7.1 Project Management Constraints or Triangular (PMI Inc., 2013)

It is easier to understand through *Figure 2.7.1* every factor has the chain-effect reaction to the other one or all. The quality is standardized by benchmarking to the best practice and following the international guidelines. Currently, one of the most influential player in the ERP market

is SAP (Magal & Word, 2012). The required modules is exactly the same the modules offered by SAP ERP.

Generally, the submodules is the one that will most likely determine the functionality expectation. It will generally covers: *Sales Distribution* (SD), *Production Planning* (PP), *Material Management* (MM), *Finance* (FI), *Controlling Operational* (CO), and *Human Capital Management* (HCM).

Also, it is very common for businesses to follow the International Organization for Standardization (ISO) to deal with certain fields. In order to ensure the quality of software and system, the project management team follows ISO 25000.

Figure 1.1.2 describes one of the business activities modules. There are more other than Order to Cash (O2C) there are Request to Stock (RTP), Forecast to Stock (F2C), and Hired to Fired (H2F). This paper on limit its scope to O2C but will discuss the other activities since there will be chain reaction effect.

2.8 ERP implementation concept

Implementing ERP is the same as any other project that are more tangible. It also has project lifecycle and value management. It is more challenging due to its unpredictability of resources to get the job done as planned. Project Management team are asked to be flexible and monitor the progress to ensure that the cost does not exceed the value. If the actual value exceed the planned value the team is expected to find alternative for the next phase. This paper is studying a pro-active measurement for the risk of overspending at implementation configuration phase by selecting the system that need the least modification for fitting to firm's BP. The figure below marked the position of selection within the implementation. It is a sub-project of the overall implementation project.

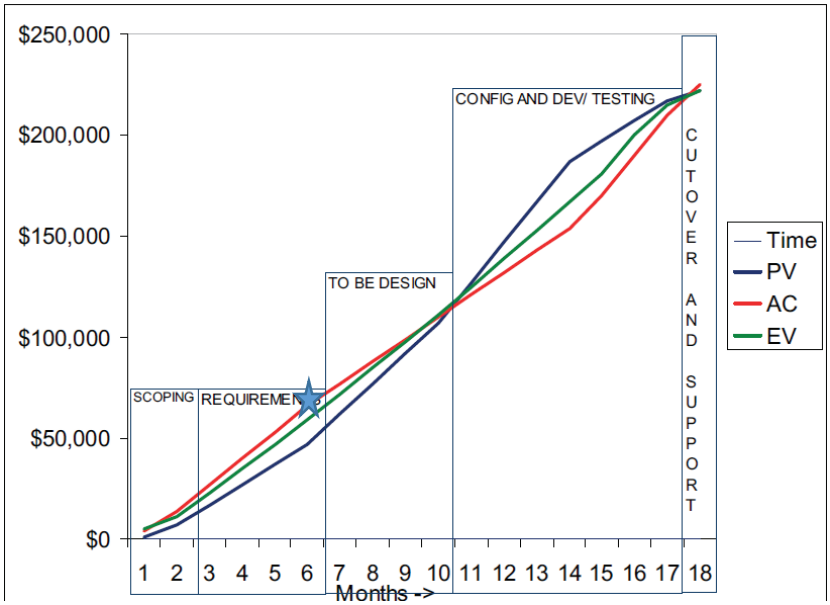


Figure 2.8.1 Example of ERP implementation Earn Value Management chart (Kotamraju, 2008)

2.9 ERP selection concept

This paper focus on the evaluation phase of the ERP selection process. To be precise it is exploring the technical evaluation method. This is the fourth step of the 'Action and Decision' at *Figure 2.9.1* during the evaluation phase.

The figure also describe the need of selecting competent project management team at overseeing the Implementation. Their skill will be needed the most at the analysis phase to find out the BP of the firm if they need to be reengineer or ready to be fitted. There are several gap in BP fitting and it is an opportunity to be included in this study.

At literature review, BP fitting is reviewed. There are several methods that previous studies had recommended. However, further study needed to be conducted to understand which method has the least flaw.

2.9.1 Selection Roadmap

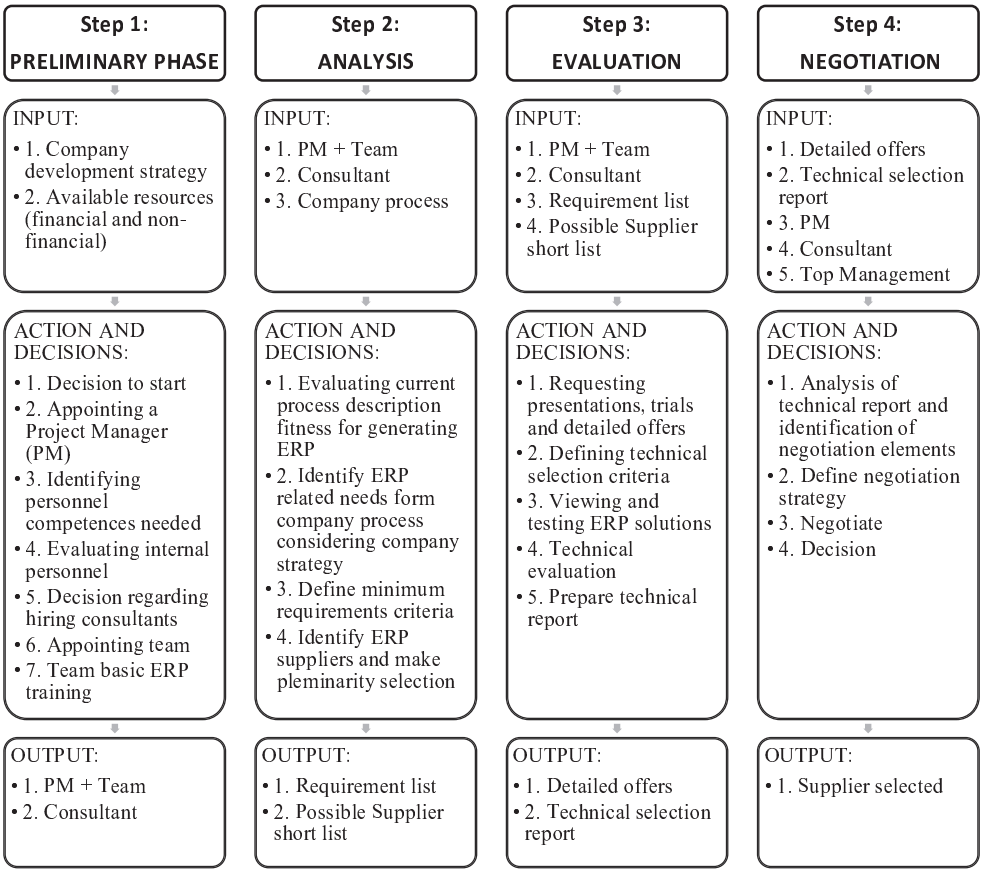


Figure 2.9.1 ERP selection roadmap (Pitic, Popescu, & Pitic, 2014)

Pitic et' Al. tried to documented the scattered work into a clear roadmap. *Figure 2.9.1* is the result of their research. It is a general roadmap of ERP system selection. Important innovation is in the selection method which involve more technicality and management. Wei and Wang used fuzzy ranking shown in *Figure 2.9.2*. It is without actually measure anything more quantitative such as comparing *Business Process Modelling Notation* (BPMN) or *Petri Net Markup Language (PNML)*. It is focus on the Business activity graphs and compare it to such as *Figure 2.6.3 Example of comparing different BP in graphs* .

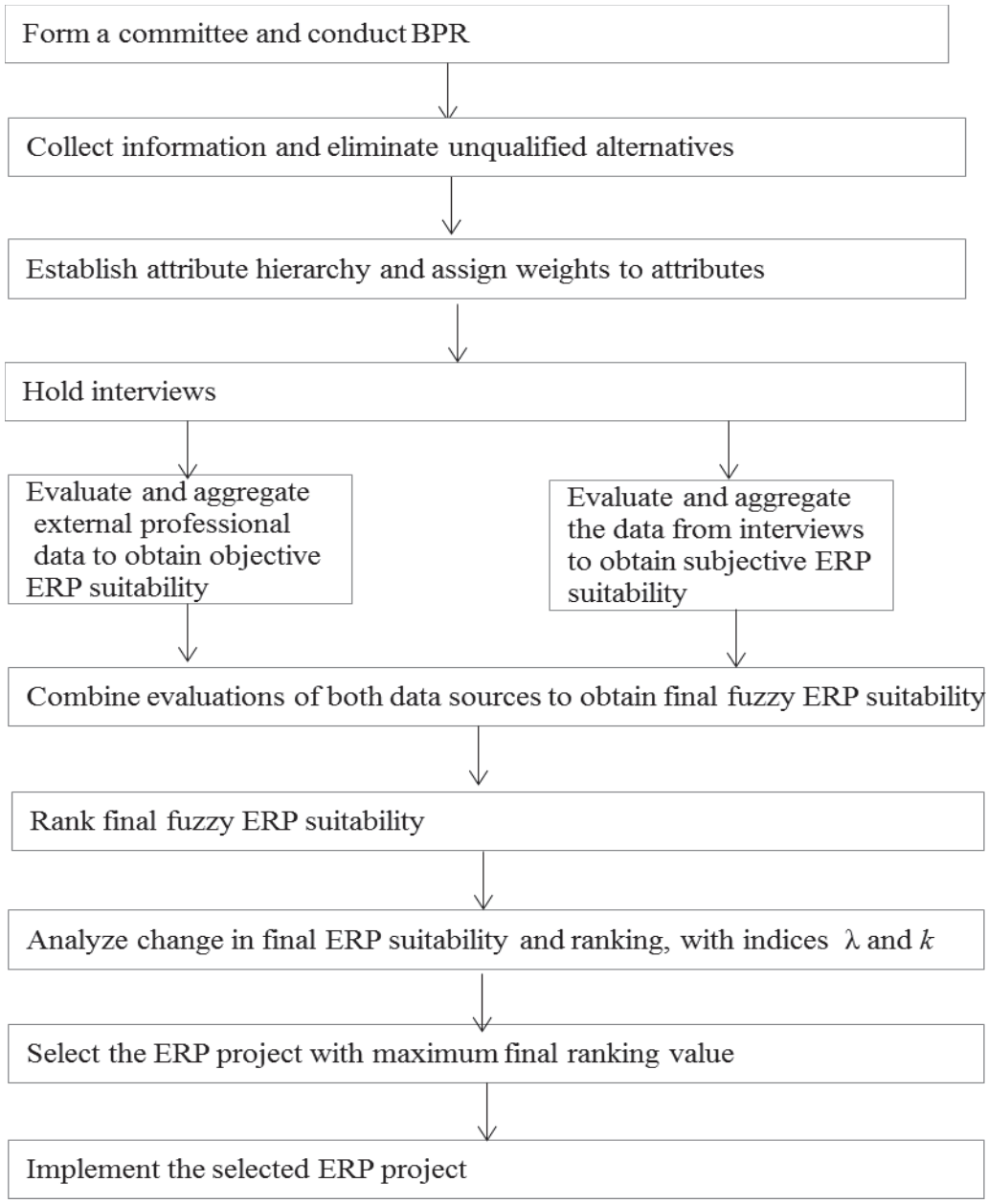


Figure 2.9.2 ERP selection procedure with fuzzy ranking (Wei & Wang, 2004)

2.9.2 Criteria for selection

Common criteria among most researchers are Vendor, System, and Investment. It is depending on the scope of the researcher. Below on *Figure 2.9.3* is an example of two criteria, the investment or financial measures is embedded in vendor. This taxonomy became an inspiration on how to design the criteria.

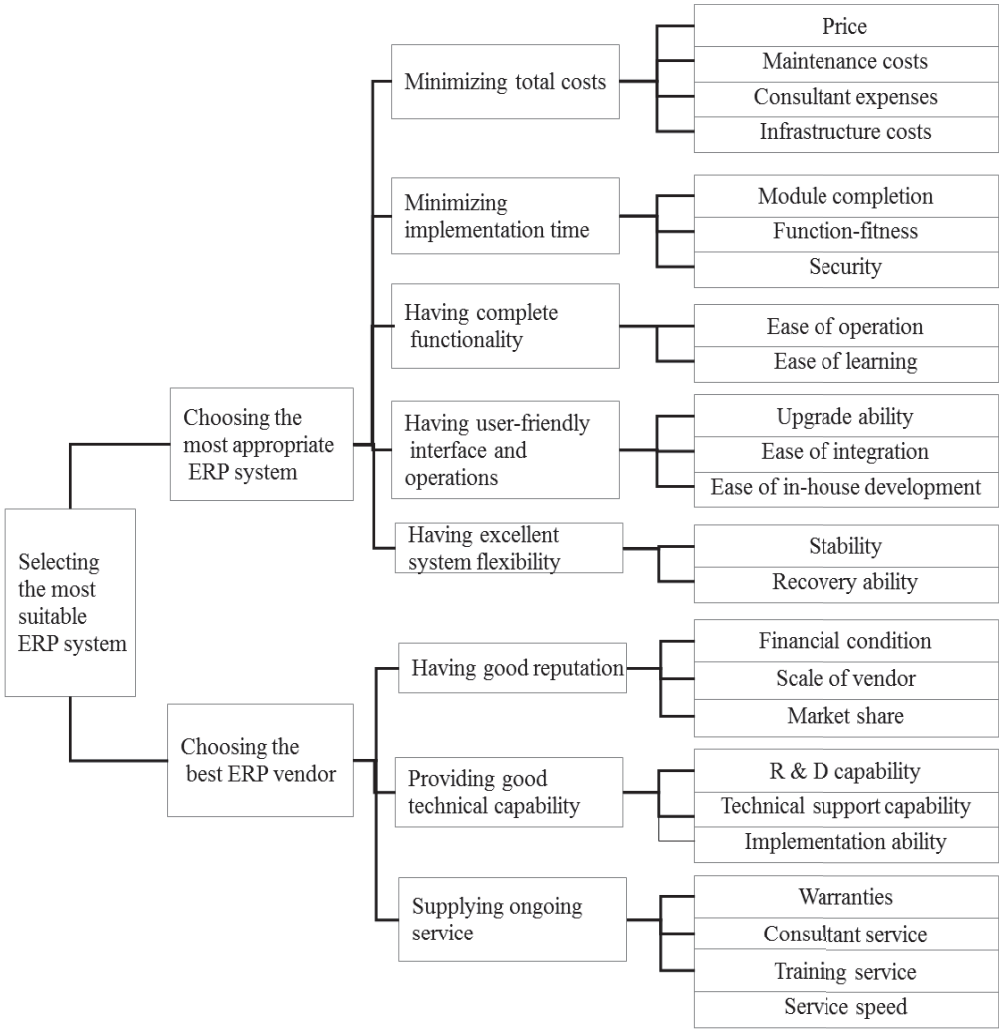


Figure 2.9.3 ERP selection AHP criteria (Wei, Chien, & Wang, 2005).

2.10 Scale

The criteria will be weighted by decision makers at this case is the IT experts. They will give a linguistic opinion which will be quantified using fuzzy. The scale will be further explained at *Figure 2.10.1* below.

There will be a modification on this method as fuzzy implemented and perhaps there will a better modification that improve the result. Further study is required to have full understanding of method integration without jeopardizing their strength.

2.10.1 Saaty's Scale

Saaty is known for the scale and has popularized AHP back in the eighties. Its method simplicity, lasted until now. For the past decades many studies have use the scale in their research. Saaty's scale usually is ended with odd numerical values.

The result with this method can be doubted because the correctness in choosing the right scale is depending on the experts' perspective. Also it does not consider the degree of membership. The possibility that it can be in between. Therefore the scale usually elaborated in with fuzzy set.

Table 2.10.1 Example of Saaty's scale

Intensity of Importance	Definition
1	Equal importance
2	Weak
3	Moderate Importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

2.10.2 Triangular Fuzzy Scale

This theory has been introduced since 1965 by Zadeh to interpret the verbal concept into mathematical theory (Barreiros et. Al., 2010). Fuzzy scale gives a degree of membership of every linguistic evaluation (Zadeh, 1965). It is more suitable scale for non-probabilistic study. Below is an example of fuzzy scale.

Table 2.10.2 Level of significance fuzzy scale

		Vector				
Level of Significance		**a**	**b**	**c**	**d**	**Rating**
Very Important	**VI**	0.7	1	1	1	100%-70%
Important	**I**	0.5	0.7	0.7	1	100%-50%
Fair	**F**	0.2	0.5	0.5	0.8	80%-20%
Weak	**W**	0	0.3	0.3	0.5	50%-0%
Very Weak	**VW**	0	0	0	0.3	30%-0%

- Vector a is lower bound
- Vector b is middle bound 1
- Vector c is middle bound 2
- Vector d is upper bound

Source: (Barreiros, Grilo, Cruz-Machado, & Cabrita, 2010)

Figure 2.10.1 below is an example if vectors being graphs with seven linguistic labels. Fuzzy usually is in a shape of trapezoid. However, it can be shaped triangular if the vector b and c are similar. Sometimes scoring in linguistic label can be difficult.

The linguistic label can be converted to Saaty's scale as alternatives scale if some of the expert prefer to use scale instead of the linguistic label. Every linguistic label will also represent a numeric number of Saaty's scale. The lowest value will be matched with the lowest number. This will be useful during the data collection phase of the research.

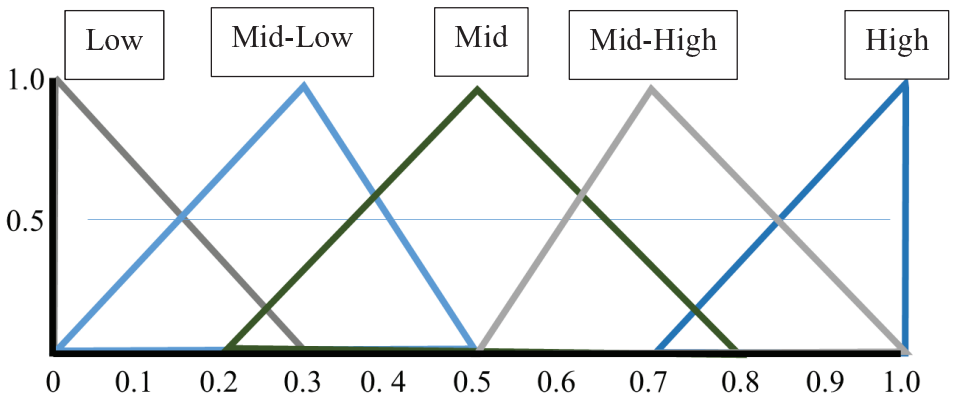


Figure 2.10.1 Fuzzy scale chart representation with linguistic label (Barreiros, Grilo, Cruz-Machado, & Cabrita, 2010)

2.11 Methods

All methods are scoring and ranking. However, some are simple and some are complex approach. Some literature with Small and or Medium Enterprises (SME) scope chose simpler method implementing with

Analytical Hierarchy Process (AHP) or Simple Multi-Attributes Rating Technique (SMART).

Fuzzy set theory is the most popular method as experts accurate evaluation became necessary. It is combined with other methods as well since all methods still needs experts' inputs. This can be combine with more complex methods such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Measuring Attractiveness by a Categorical Based Evaluation Technique (MAC-BETH), Analytic Network Process (ANP), Artificial Neural Network (ANN), Multi agent system, or Multi-Criteria Decision Making (MCDM). At this case, this research is combining it with Business Process similarity, COCOMO II, and scoring. There has not any literatures testing the accuracy of each method. This research will compare it to fuzzy set method.

Figure 2.11.1 Methods used in literature review

No.	Methods	Reference
1	Simple Scoring and Ranking	7, 11, 14
2	FUZZY	1, 5, 8, 9, 13, 15
3	AHP	2, 3, 5, 9, 11
4	MCDM	4, 6
5	TOPSIS	4
6	PROMETHEE	4, 17
7	MAC-BETH	11
8	ANP	6, 11, 15, 17
9	ANN	6
10	SMART	12
11	Multi Agents system	10

- Look at Table 2.13.1 Literature Review ERP

Five of the seventeen literatures discussed about business process in regards to the effect of the system module mismatch and how it effect the benefit of ERP implementation. Three out of the five proposed business process matching. Two of them used experts to rank the alternatives based on completeness and one use Petri Net Markup Language (PNML). The others simply following the previous software quality ISO 9126, or

collaborate their selection with other evaluation technique such as Balance Scorecard, Supply Chain Performance Management (SC-PM), Total Ownership Cost (TOC), and others.

Some of the literatures' scope were on SME, one was for construction industry, and three were for Manufacturing. The scope determine the complexity of methods needed. The most complex ERP is the ERP. A simple method of scoring and ranking will undermine the fatality of wrong selection.

2.11.1 Delphi method

There are two Delphi techniques to reduce prejudice in the data:

- Focus Discussion Group – obtain data from a group through several questions but more critical
- Experts' judgement – facilitator use questionnaire to gather the data from specific expert in that field.

Both has weakness and strength. Related to this study it is better that the technicality will be conducted with Experts' Judgment and the satisfactory of the managerial can be asked to the direct user.

2.11.2 Fuzzy Multi-Criteria Decision Making

MCDM method has the flexibility to implement fuzzy further in the weight and the value of each criteria based on multiple experts perspective. Whereas, fuzzy AHP evaluation will be constraint to one expert. Fuzzy set MCDM introduced by Wang and Chang in 1995 and improved by (Chen, 1997). The fuzzy MCDM method will need a scale of measurement as explained on section, Triangular Fuzzy Scale.

The MCDM taxonomy will be arranged from the variables based on ISO/IEC 25022. The measurements will be elaborated with COCOMO II to enhance its constructive cost estimation and hoping to give more precise economic value from the procurement project. PNML will be used to help measuring the BP similarity.

2.12 Electre III

This is a method to sort the criteria measurement that will be used in this research. It is a scoring that will be done by the experts on all the criteria to rank the importance (Ishizaka, 2013). They will be given a scale of 1-9. An average of every criteria will be taken and only the very important or anything above the scale of eight will be selected.

Table 2.12.1 Sorting scale for narrowing the ISO measurement criteria

Saaty scale	Level of Significance
8.01 - 9	Extremely Important
7.01 - 8	Very Important
6.01 - 7	Important
5.01 - 6	Between Fair and Important
4.01 - 5	Fair
3.01 - 4	Between Fair and Weak
2.01- 3	Weak
1.01 - 2	Very Weak
0 - 1	Extremely Weak

2.13 Research position

Research position Table 2.13.1 and Table 2.13.2 are showing the gap between or weakness from previous studies. It will show the main reason of why this research is initiated. Literatures reviewed in this paper mostly a combination of ERP with varies of methods to understand further about selection decision.

The contribution of this research:

- Identifying the criteria based on ISO
- Measuring the scope of work based on BP similarity
- Optimizing the ERP selection using fuzzy MCDM
- Reduce the reliance or dependency to ERP expert

Table 2.13.1 Literature Review ERP

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
1	(Wei & Wang, 2004)	ERP Selection framework	Unable to select the suitable vendor with several constrains such as: Limited resources, diverse alternatives, time.	It is to have a usable ERP selection framework	There is a valid framework
		Business Process (BP)			
		Fuzzy Ranking set	Minimize the work for Business Process Change		
2	(Wei, Chien, & Wang 2005)	ERP Selection System	Appropriate attributes to select ERP can be debatable (ISO 9216)	Select one out of the 3 systems based on the business goals and strategies	There are standard for criteria
		Analytical Hierarchy Process (AHP)			
		multi-attributes	Doesn't have framework for selection		
		Business goals and strategy			
3	(Alanbay, 2005)	ERP Selection	Choosing ERP is a complex decision with significant financial consequences	Simplify the complexity with multi-criterion approach	Expert Choice Decision support software able to perform ERP selection
		Expert Choice Software		systematic approach of AHP To encourage people to use AHP methodology	Reduce implementation cost: training cost
		AHP			
		multi-attributes			
		Business Requirement			

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
4	(Razmi & Sangan, 2008)	ERP selection Hybrid MCDM Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) Organization Requirement	inadequacies and limitation in previous models	Select simple and appropriate method for real world problems in selecting system	Final ranking of system alternative can be reached by TOPSIS and PROMETHEE methods
5	(Cebeci, 2009)	ERP selection Fuzzy AHP Textile Industry Balance Scorecard	Textile companies have variety of product structures, production, and unqualified Human Resources. This became hindrance to implement ERP	Selecting system for textile industry	Fuzzy AHP can overcome the difficulties in selecting ERP
6	(Yazgan, Boran, & Goztepe, 2009)	ERP software selection Analytic Network Process (ANP) Artificial Neural Network (ANN) multi-criteria decision making (MCDM)	Attributes relations are not analyzed and how it effects the ranking or the selection result	Proposed other method other than AHP to select ERP Does ANN can reduce group decision	Relations of each attributes/sub criteria will affect the attributes weights and the final result of the selection

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
7	(Forslund & Johnsson, 2010)	ERP system selection Implementation in Manufacture Supply chain management (SCM) Performance Management (PM) Resource Management	ERP become the major obstacle for SC-PM	The effect of ERP system lifecycle phase decisions towards SC-PM	ERP affect the performance of SC in different lifecycle
8	(Barreiros et. al, 2010)	ERP selection Fuzzy sets theory Construction Industry Business Process (BP) Implementation	Mismatch between system and BP or strategy jeopardize implementation successfulness.	Apply fuzzy sets to improve the system selection for construction industry.	Fuzzy sets methodology can be adapted for selection process.
9	(Shih, 2010)	ERP selection Fuzzy AHP (FAHP) small enterprises Implementation Function and Cost	Critical factors to select ERP should support the business goals and strategies.	Evaluate the relative importance between selection ERP criterions.	Enterprise and function objective are the most critical factors
10	(Comer & Castolo, 2011)	ERP selection Implementation Evaluation criteria Petri Nets Multi Agents system	Disorganization of ERP implementation, Critical success factor, and critical success factors.	Present an implementation and selection process proposal with Petri Nets and Multi Agent System	Petri Nets and Multi Agent system can aid selection system

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
11	(Gürbüz, Alptekin, & Alptekin, 2012)	ERP selection Hybrid MCDM Analytic Network Process (ANP) AHP Choquet Integral (CI) Measuring Attractiveness by a Categorical Based Evaluation Technique (MAC-BETH) Final Ranking	Most selection methods do not account relevancy among criteria	Research the importance of criteria relevancies	Ignorance of the criteria Interaction leads to incorrect decision
12	(Haddara, 2014)	ERP selection Simple Multi-Attributes Rating Technique (SMART) Matching Business Process (BP) Fitting and project failures Benefits	Selected system failed to fit the Business needs because of misfit process and project failure and resources loss as consequences	Minimize risk of non-fitness system to the Business Process Requirement	Fitting method for selection process increase the system implementation successfulness
13	(Kilic, Zaim, & Delen, 2014)	ERP selection Total Ownership Cost (TOC) Fuzzy logic Analytical Hierarchy Process (AHP) Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS)	Selection method needs to be improved as failure still happened. It is the most critical phase before implementation and use	Combined popular decision support methods	Selection process can be more scientific to select out of large number of systems
14	(Pitic, Popescu, & Pitic, 2014)	ERP selection Evaluation Roadmap Implementation Business Process (BP) Small Medium Enterprise (SME)	Inadequate selection process or not fit system to the needs. Fuzzy AHP is difficult to be applied and time consuming	Proposed a 'keep it simple' ERP selection process method for SME	A simple roadmap with careful consideration for business needs and BP current and future state.

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
15	(Boltena et al., 2014)	ERP selection criteria	Greenness of ERP system should be evaluated	The criteria that emphasis on criteria to identify green ERP alternatives	There are suitable criteria for assessing the greenness of ERP
		Corporate Environmental Management Information System (CEMIS)			
		ISO 9126 criteria			
		Matching Business Process			
		Analytic Network Process (ANP)			
		Fuzzy			
16	(Pattanayak & Roy, 2015)	Business Process Reengineering (BPR)	Investments in capital goods sector have declined with decline in relative profitability of capital goods sector vis-à-vis the other sectors.	To synergize Business Process Excellence (BPE) with ERP at HEC Ltd. by identifying the actionable strategic initiatives and implementation plan.	If there is still a challenge in synergizing BPR to ERP through direct implementation
		ERP	BPR projects fail to meet expectations not as it should.	Show the benefit of integrating reengineered business processes through ERP system in use.	
		Synergy and alignment	Dynamic Organic BPR is not fully understood	Mapping Heavy Engineering Corporation (HEC) BP for further study in other capital good sector.	
		Critical success factors (CSF)	BP grow in respond to Organization grow, which latter demand ERP to follow. Misalignment between BP and ERP happened	To prove the need to adopt BPR and ERP as business competitive strategy	
		Business Process Management (BPM)			

No	SOURCE	BACKGROUND			THEORY OF CONCEPTS/ HYPOTHESIS
		SCOPE	PROBLEM STATEMENTS	PURPOSE	
17	(Kilic, Zaim, & Delen, 2015)	ERP selection Small Medium Enterprise (SME) Analytic Network Process (ANP) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) Small Medium Enterprise (SME)	Implementation is a costly and risky phase that needs the right ERP system.	Apply ANP and PROMETHEE to the selection process	ANP and PROMETHEE hybrid method able to mitigate the risk of mismatched system selection.

Table 2.13.2 Literature review in methodology

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
1	(Wei & Wang, 2004)	fuzzy set theory integration model that uses the fuzzy average method and fuzzy integral ranking	4 alternatives Unknown number of experts	A roadmap that organized and sort of standardize the selection process.	The managers were satisfied with the framework. the cost of ERP project implementation and maintenance were reduced	All alternatives are filtered by Questions. COST and flexibility	undermine the seriousness and the complexity of the needs or project	simple
2	(Wei, Chien, & Wang 2005)	numerical scale 1-9 (crisp)	3 alternatives	Models of hierarchical and network structures ERP selection obstacles	Chosen system A	Semantic description Score ambiguity	Time consuming to compare	The scoring can be ambiguous without fuzzy
		Set criteria and tell 3 Decision Maker to score	pairwise comparison AHP	It is flexible enough to add attributes or decision makers mitigate the resistance of invisible cost		Decision Makers' knowledge		

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
3	(Alanbay, 2005)	Evaluate alternative software	2 ERP systems	Mostly appropriate to use AHP for multi-attributes and multi- alternative dilemma.	Easy to learn methodology	Assumed module selection process were functional	Limited to those alternatives.	Handle the large enterprise which is the most complex
		determined criteria: technology, user, and vendor related	Production, Financial manager, and End user perspective	Weight of each sub-criteria matters	Result may change depending on weight	Large enterprise		
		determined the modules of each system			Axapta chosen over SAP	Assume experts' knowledge are reliable		
		determined business goals: reduce training cost						
		sensitivity analysis						
4	(Razmi & Sangan, 2008)	4 different perspectives: vendor, system, project, finance	5 groups calculate weights	4th Alternatives is the best	Superior alternatives have shorter distance to ideal reference	Limited to the hybrid method not the criteria	Vagueness in expert judgments: proposed fuzzy	PROMETHEE avoids trade-off between good/bad scores
		organizational requirement reflected through business process modeling						
		TOPSIS to weight the variables	Apply to Iranian power holding company	Sensitivity analysis used to aid the decision makers			Criteria importance need to be researched	
		PROMETHEE to rank						
5	(Cebeci, 2009)	Use Balance Scorecard to check the vision and strategies to prepare Request for Proposal (RFP)	73 companies participate in this study	Applied successfully for textile manufacturing	Humans' uncertainty measured in crisp or descriptive score. Fuzzy overcome the difficulty	Other various field of department	The method did not choose technical attributes as the superior attributes	Expert system can help RFP
		Criteria determined and ranked						
		Apply fuzzy AHP						Improve human consistency for decision making
		Questionnaires prepared to aim the degree of preferences						

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
6	(Yazgan, Boran, & Goztepe, 2009)	ANP drew the sub criteria based on one person	17 sub factors 30 persons	ANN is capable to predict the selection system with single or group decision maker with best error rate 0.07	ANN successfully predicts result from objectivity (for example synthesis of experts' decision). To reduce group decision	Only seeing new method not criteria	The study did not proof that it is better nor worse than AHP	The scholars were able to proposed effective alternative method for selection
		ANN calculate and ranked priority based on 5 people	4 alternatives					
		Matlab software as tool						
7	(Forslund & Johnsson, 2010)	Data were collected from 4 manufacturing companies	4 manufactures	8 proposition were made to improve and one of them is selection	Room for improvement in selection of ERP, education, training, interface friendliness, & customization	Explorative, need to test on larger sample	Qualitative without calculation	The writers able to deliver in easily to understand structure
8	(Barreiros et. al, 2010)	Define the vectors of fuzzy sets linguistic labels for scale	3 alternatives	method of selection also need critical factors to lead towards successful implementation	ERP 1st alternative selected for the highest rating based on the sum of (avg weight of each criterion * the relative weight)	Only adding fuzzy sets into ranking selection method	Rely mostly on experts	Experts' inputs are not bias.
		Values inputs rely on experts	4 decision makers					
		Calculate the weights	5 scale satisfaction levels					
		Calculate each alternatives score	9 scale for linguistic attributes					
		Final rating of each alternatives	Fuzzy suitability index					

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
9	(Shih, 2010)	Create hierarchy	6 factors	CEO decision and company finance are most important criteria	Most important in order i.e. Enterprise 35.73%, Functionality 26.88%, purchasing cost 14.87%, consultant 8.43%, software 7.74%, and supplier 6.25%	Focus on the relevancy of criteria	Sub criteria of finance doesn't relate to Cocomo (Boehm)	Found the priotized criteria
		Create fuzzy pairwise combination	26 sub-factors					
		Buckley geometric mean method to combine experts' pairwise combination.	100 questionnaires issued and receive 30 effective responses					
		Build fuzzy reciprocal matrix and compute the fuzzy weight						
		Defuzzification						
10	(Comer & Castolo, 2011)	Review all literature review	38 papers about CSF, implementation and selection of ERP	Integrate implementation methodology	Identify that functional, technical, economical, and operational should be the main criteria	Ongoing research: Petri nets a computational modeling could reflect the complex behaviour and help automate selection process.	Ongoing research	Possibility that reducing expert reliability
11	(Gürbüz, Alptekin, & Alptekin, 2012)	ANP and AHP to capture tangible and intangible aspect	4 alternatives	High cost and high implementation risk	Proposed method flexible enough for changes in different characteristic	Select alternatives A1 as it gives the highest final performance score 0.6867	Ignore the payback period of the system investment	Account the criteria interaction into the decision
		CI introduce fuzzy measure for weight	3 criteria: vendor, Customer, Software	complex environment increase the selection problems				
		MACBETH for the multicriteria decision analysis. In this case is being used for finding CI parameter		Hybrid of 3 methodologies	Importance not to ignore the interaction among different criteria			
		Evaluation procedure						
		Selection criteria						
		Decision framework						

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
12	(Haddara, 2014)	Qualitative research approach	3 alternatives: SAP All in One, SAP Business-one, SAP By Design.	few studies present in actual real-life cases	SAP Business-one selected	Method increase scope to include Business Process but limit to the method accuracy as further research needed	Measurement of fitness were not quantitative	Propose a good point of view to include BP and benefits to the company
		Business vision and evaluate benefit of ROI/value	applied to ABC company					
		Data collection from all employees	11 criteria factors	B-one total cost of ownership is less than All-in one			Alternatives compare were from the same vendors	
13	(Kilic, Zaim, & Delen, 2014)	AHP build criteria	9 scales saaty to fuzzy	Result is both technically and organizationally acceptable	Alternatives A is chosen for Turkish Airlines	Only aviation industry	Rely on experts most of the process	Simple and well documented
		Pair-wise comparisons	Pre-evaluation, fuzzy AHP, TOPSIS stage			Heuristic one		
		(objective, attibutes, sub-attributes, and alternatives)	3 criteria: technical, corporate, financial			Optimal solution is not guaranteed	The study does not account fitness of BP	
		Fuzzy for vagueness	12 sub-criteria			Hybrid method		
		TOPSIS to rank based on distance	Turkish Airlines data set			Other MCDM (PROMETHEE, VIKOR, ELECTRE		

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
14	(Pitic, Popescu, & Pitic, 2014)	Experience in related software implementation	Empirical evidence from mid-size distribution company	The process proposed are devided to 4 phases: In the preliminary phase output is Project Management (PM) team and consultant, Second phase is Analysis (fitness), Evaluation of alternatives and technical reports, and last is Negotiation.	ERP Roadmap	SME	Highly rely on consultant and PM team skills	The Roadmap is very useful regardless the final selection method
		Work with consultants and implementers			Software evaluation (score by supplier and internal)	low level of available resources	Scoring is full of vagueness	
		related literatures	Applied to mid-size company with 200 employees and 20 million EUR turnover/year		Selection with scoring based on 4 criteria (Software solution, implementation, Total Cost of Ownership - TCO), supplier)	distribution department	Manufacturing is more complex business process	
		Quality management practice and principles					Undermine the needs of due diligent	
15	(Boltena et al., 2014)	Extracting criteria	ISO 9126 criteria and sub criteria	pairwise comparison process is important in evaluation of ERP alternatives	Suitable criteria: Modularity, Scalability, Customization, Flexibility, and Technology	Exclude meta-analysis study	Green dimension (Social, Economic, Environment) can be included in the enterprise requirement	Encourage vendor to improve modules
		Ranking	30 criteria					
		FANP						

No	SOURCE	METHODOLOGY			RESEARCH RESULT	RESEARCH LIMITATION	WEAKNESS/ LACKNESS	STRENGTH
		RESEARCH METHOD	SAMPLE	FINDINGS				
16	(Pattanayak & Roy, 2015)	Roadmap Or BPR Value Map to HEC Ltd.	Object: HEC process flow Foundry & Forging Plant (FFP), Heavy Machine Building Plant (HMBP) & Heavy Machine Tools Plant (HMTP)	BPR needed first to use ERP to improve business competitiveness	ISOMETRIC WORKING MODEL to synergize BPR and ERP that link B	Limited application, has not been applied to other capital goods industry	The documentation of the result was not written in table which became difficult to follow.	The problem was real-life case which often happened.
		Conceptual inputs of theorist and best practice of the industry	HEC 4 Strategic Business Units (SBUs) = 3 Plant setups described above and a Project Division undertaking EPC contracts.					
		Apply the 7 levers (People, Process, IT, Governance Structure, Policies, Matrices and Data.						
17	(Kilic, Zaim, & Delen, 2015)	Literature review and expert view for Pre-evaluation phase (criteria and alternatives)	Applied selection to a group of organization in Istanbul, Turkey	Combination of the methods shows optimal mapping between the needs and alternatives	Every weight depends on SME's perception.	Focus on Turkish SMEs	Vagueness of the experts scoring	acknowledging that brand image matters for the business
		3 main criteria: Business, Cost, & Technical						
		ANP rank importance, outputs are the weight of the criteria based on expert views.		Cost (Purchase, Implementation, & Support) and Technical (Functionality, Compatibility, Reliability, Cross Module integration) represent 80% of the criteria	The alternatives with the highest net values is preferred		Rely on experts most of the process	
		PROMETHEE to determine the best system						

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CHAPTER III
RESEARCH METHODOLOGY

This chapter breakdown the steps of how the research being conducted. Steps taken are put in vertical process for easy understanding. Some of the outputs are presented.

3.1 Research methodology

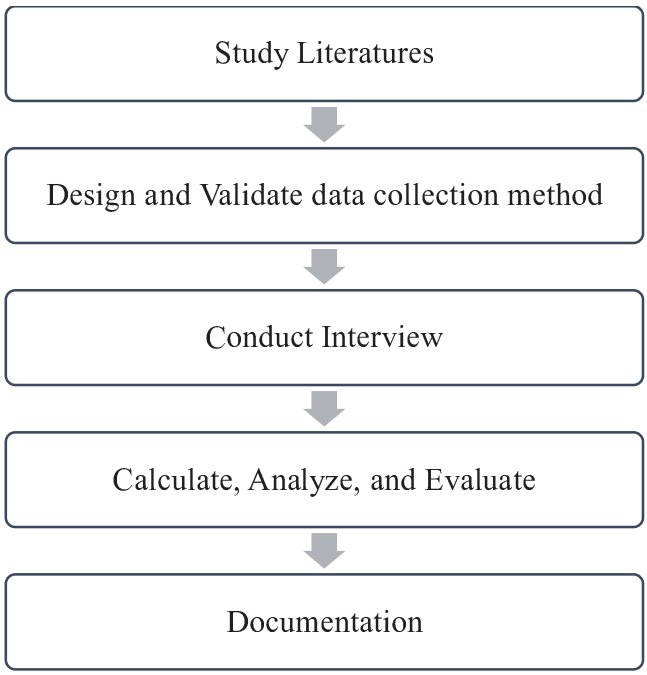


Figure 3.1.1 Research Methodology Flow

The figure above reflect the macro planning of this research. It started with the literature review to understand further about ERP and the related topic. The references of this report's documentation were gathered through:

- Online papers on science direct
- Online ERP open-source software
- Online forums
- Offline such as textbooks and related paper
- Consultation with supervisors

The research methodology is confirm with supervisors and co-supervisors. It is design based on the type of this research which is experimental.

3.2 Literature review

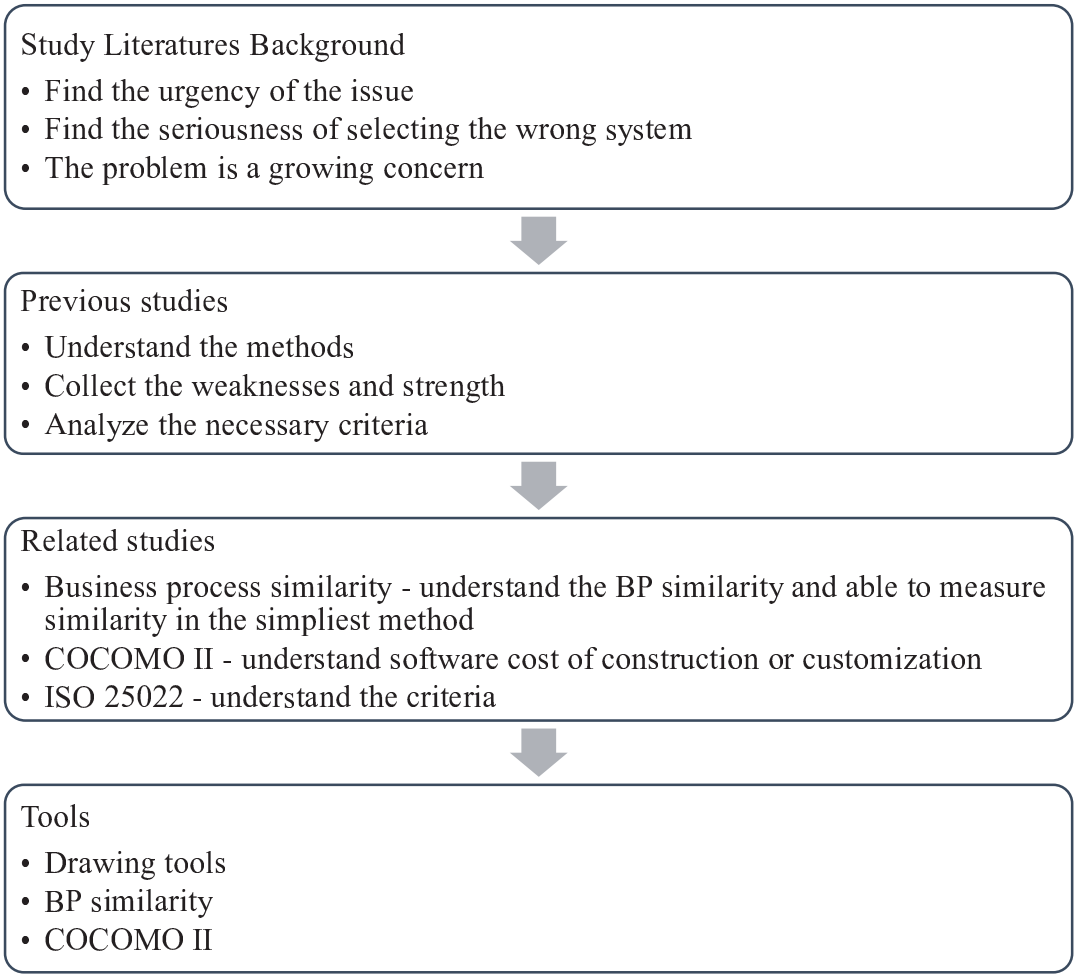


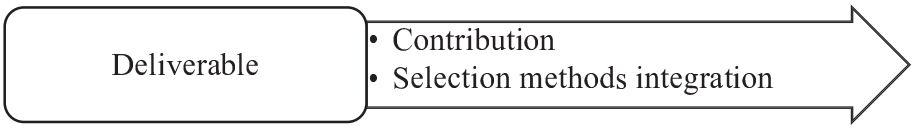
Figure 3.2.1 Literature Review Flow

Study all literature focus to only "functional suitability" of ERP

1. Learn ERP: The concept and fundamental of ERP implementation success and Risk factor based on different project. Expected output, understood the issue of implementation.
2. Selecting Criteria for MCDM: Comprehend ISO/IEC 25022 and figure out the way to elaborate COCOMO II cost drivers into it. This will resulted a better variables.
    - With the 4 decision makers the sub-sub-criteria will be narrowed down with electre tri method. This research only focus on the very important or anything with the score of

above 8. It will narrow down the critical measurement that will be used in the research. The measurement are simplified down to the pre-requisite calculation.

3. Learn Business Process: The study also include BPM and the BPR. Business requirement as output.
4. Understand the Business requirements: Specifically MTO and its effect to other activity. The value of ERP to these activities.
5. ISO 25022: find weakness
6. COCOMO II: similarity in ISO
7. BP similarity method: The amount of methods and analyze its strength and weakness.
8. Design experiment: Since this is an experimental study there will be a trial at the end. There will be a excel file calculating for Chapter 4.



9. Learn how to survey: The output is Question and selection of Expert.
   - Profiling Experts
   - Create Questions: 4 phases
10. Learn how to weight: must come up with formula modified to this research. [This support number 8]
11. Determine Scale measurements [This support number 8 and 9]

3.3 Data Collection Planning

Design and validate the data collection method:

- Previous researcher data is edited and used for attributes other than the financial measures.
- Sorting the ISO 25022 sub-sub-criteria as measurements
  - Method electre III (Result of evaluation presented on chapter 4)
  - Only anything equal and above 8 will be selected because based on pareto 20/80 rules. The 20 percent of very critical work supposed to give the highest impact on the project.

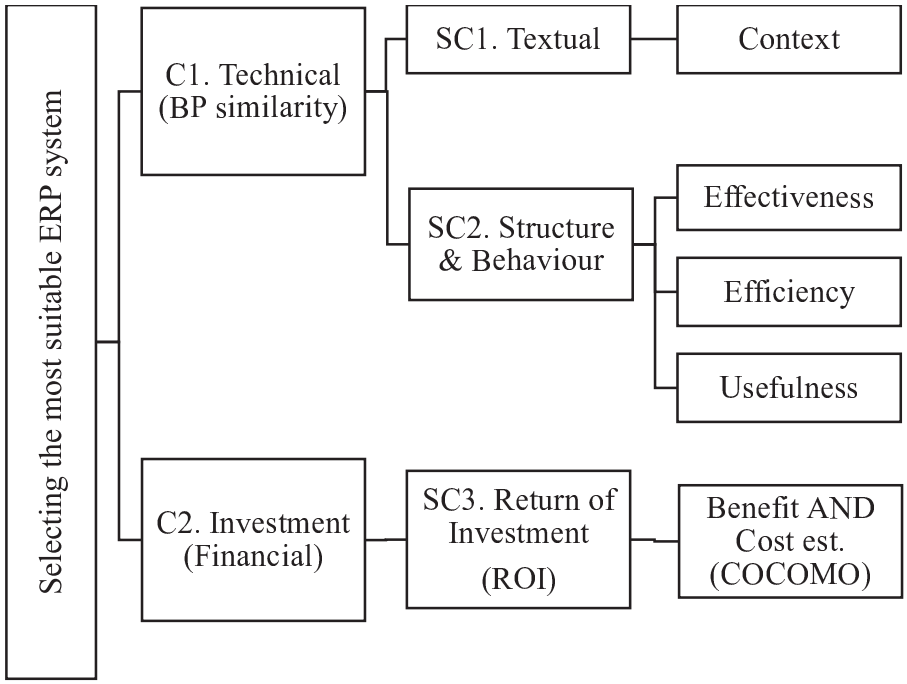


Figure 3.3.1 Taxonomy of ERP criteria based on ISO 25022 as the sub-sub-criteria

- The last five is the measurement that will be used for this research
- The *Figure 3.3.1* is what this research try to look into. The last five is what will be used

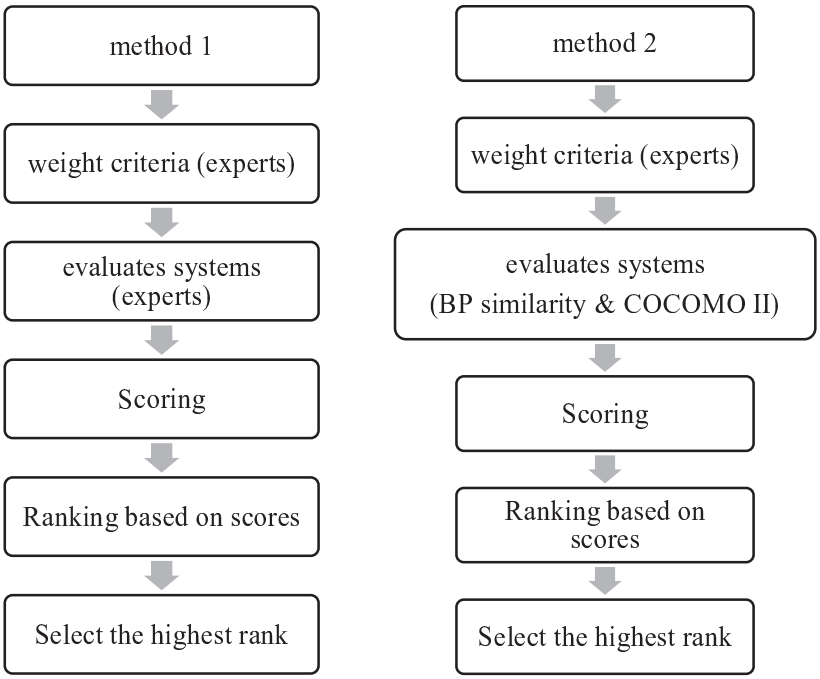


Figure 3.3.2 Comparing old method and proposed method

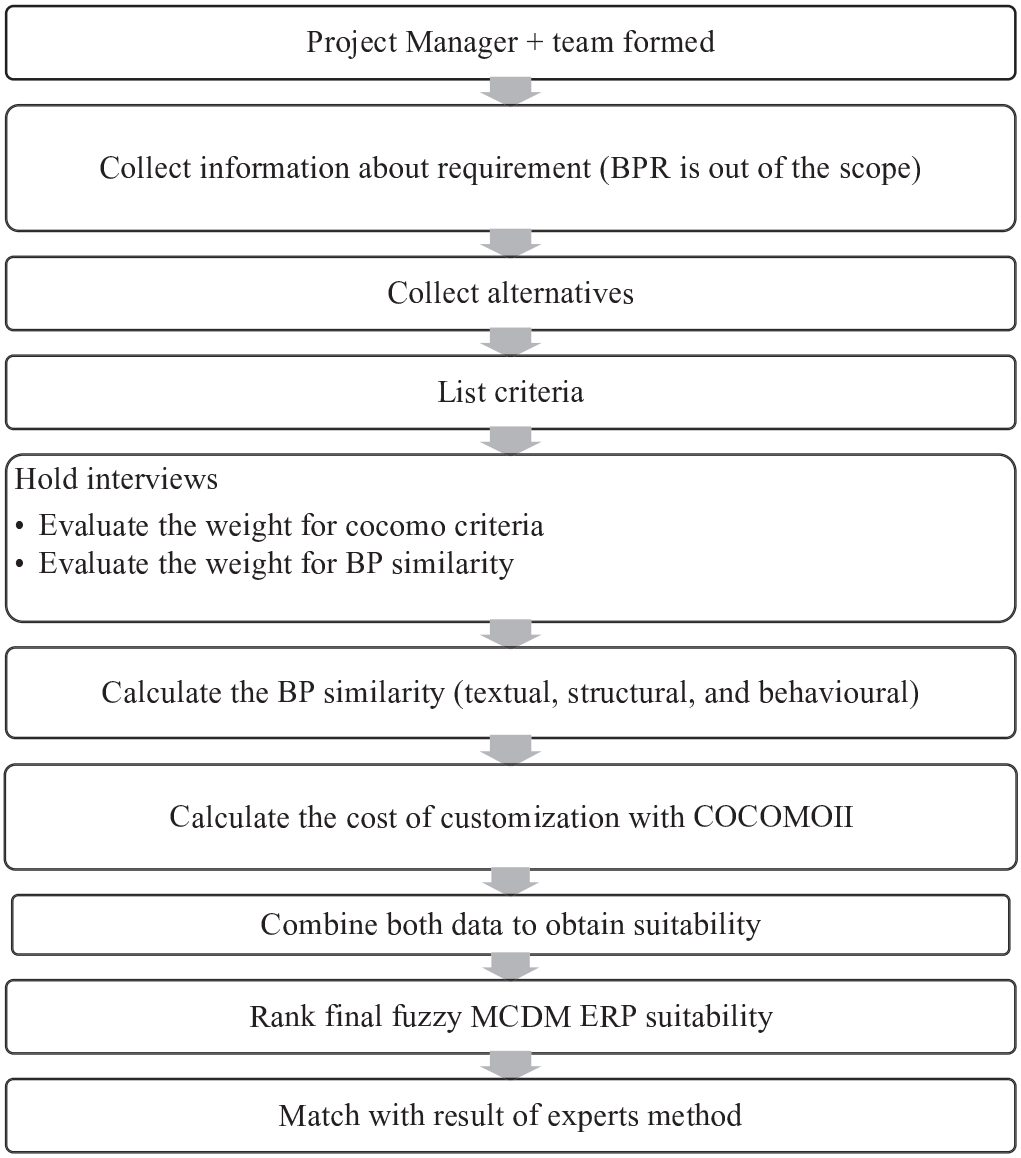


Figure 3.3.3 ERP selection procedure with fuzzy MCDM

The workflow above inspired based on (Wei & Wang, 2004) and modified as the contribution on this research. Every steps is validated through prior reseaches that are mentioned in Table 2.13.1 and Table 2.13.2. The integration of different methods is to automate the selection process. Most of the selection calculation will be done in excel. The goal is to ensure that the proposed method result the same as the experts' choice.

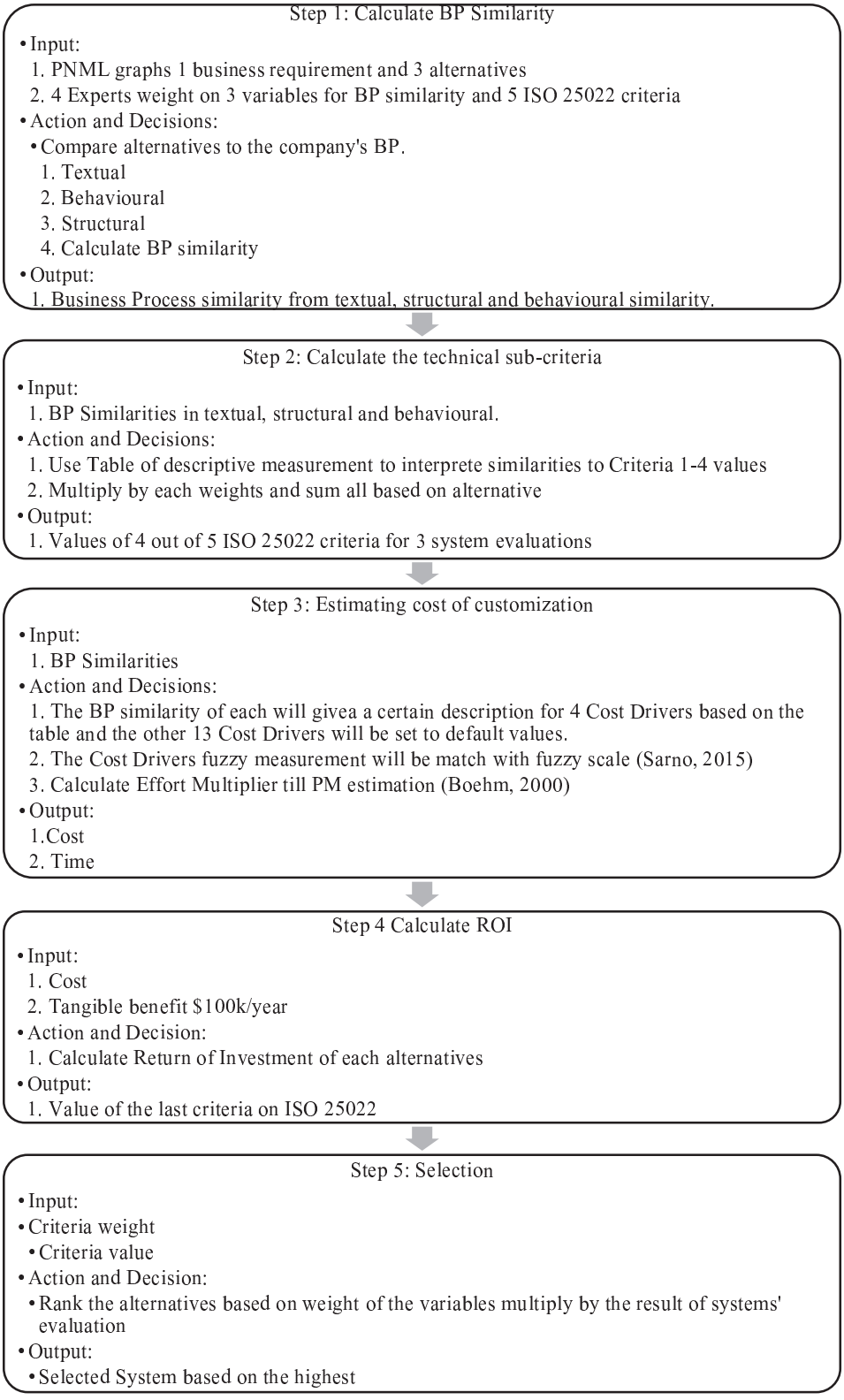


Figure 3.3.4 Proposed selection method in details

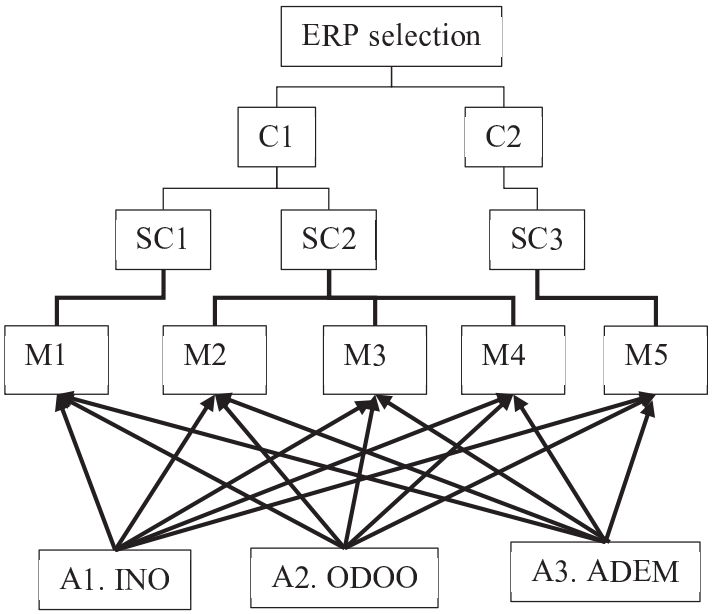


Figure 3.3.5 Proposed of the ERP selection with three different alternatives

- Draw BP of one activity with BPMN draw.io
    - BPMN use for BP visualization to aids expert such as on Figure 3.3.6.
- Draw Make to order PNML model:
    - Requirement on *Figure 1.1.3*
    - InoERP on *Figure 3.3.7*
    - OdooERP on *Figure 3.3.8*
    - Adempiere ERP on *Figure 3.3.9*

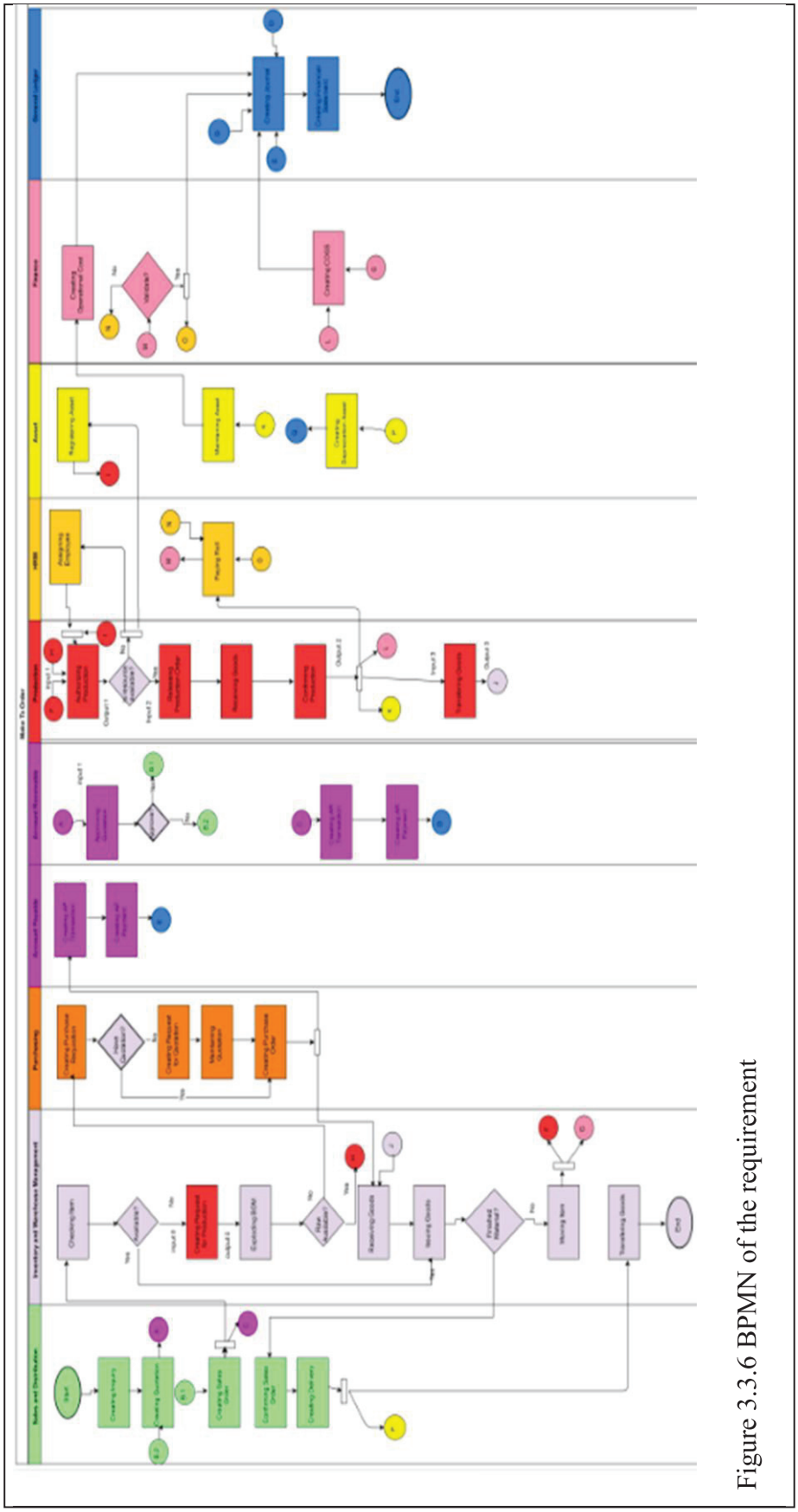


Figure 3.3.6 BPMN of the requirement

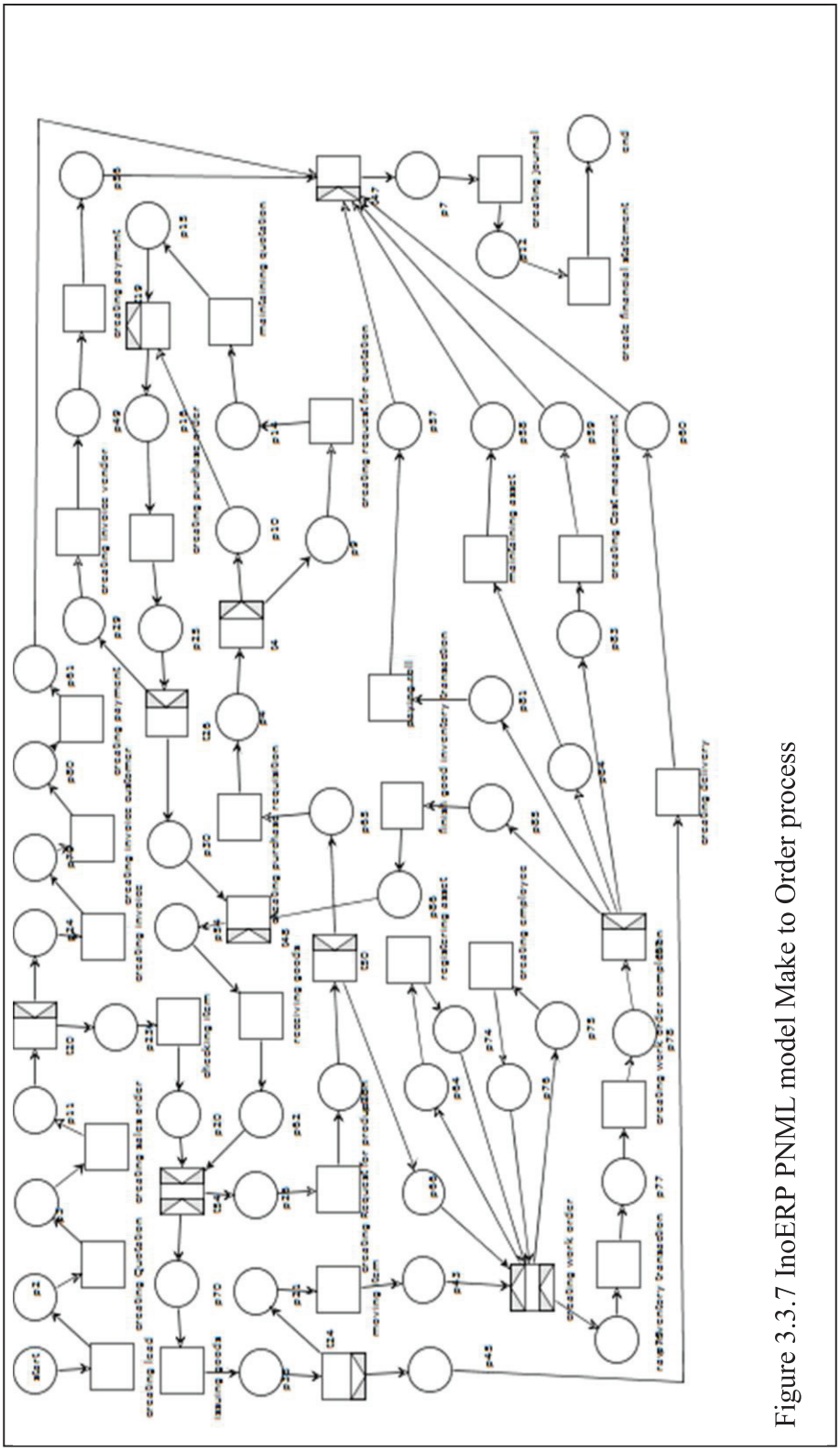


Figure 3.3.7 InoERP PNML model Make to Order process

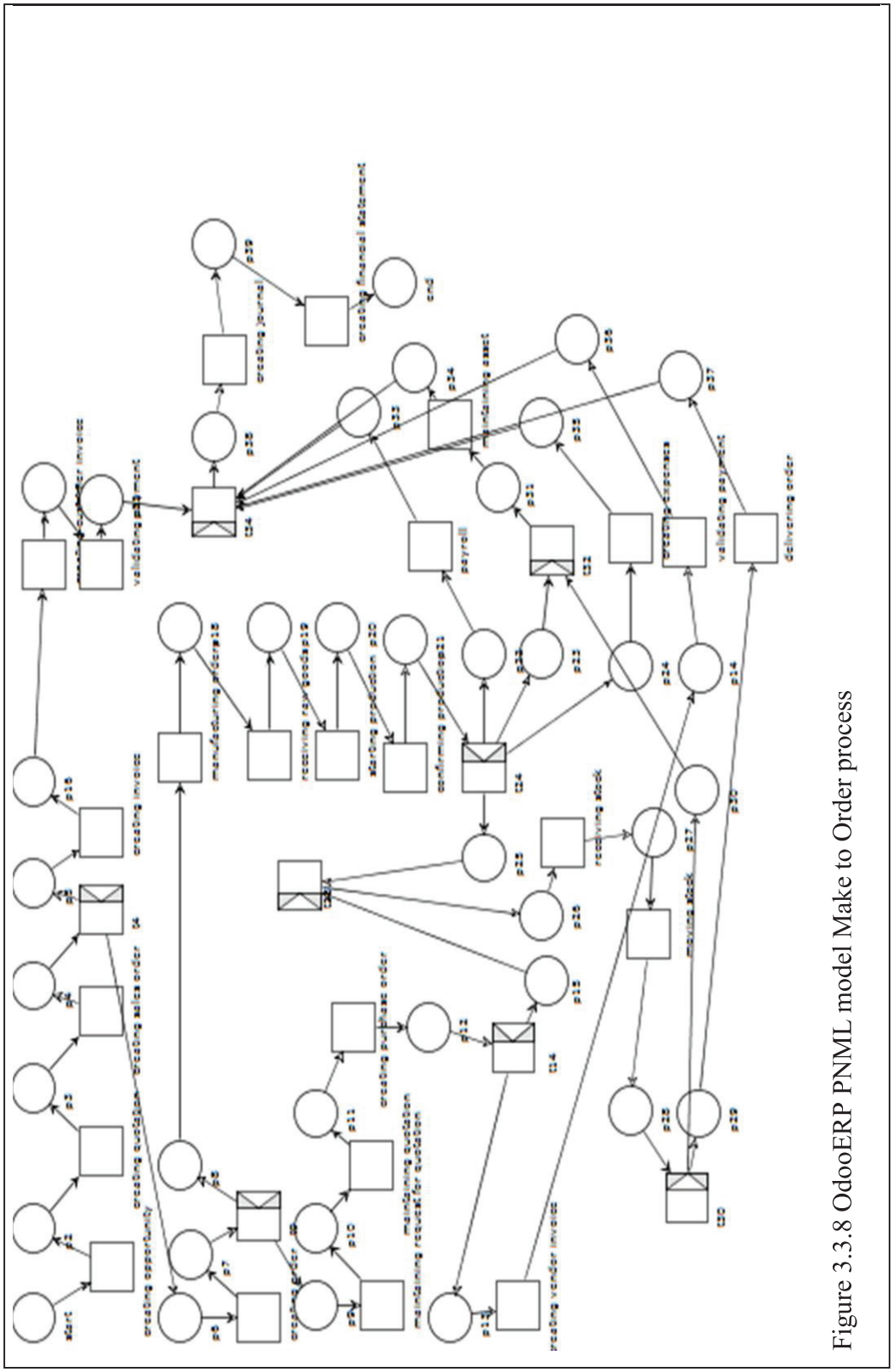


Figure 3.3.8 OdooERP PNML model Make to Order process

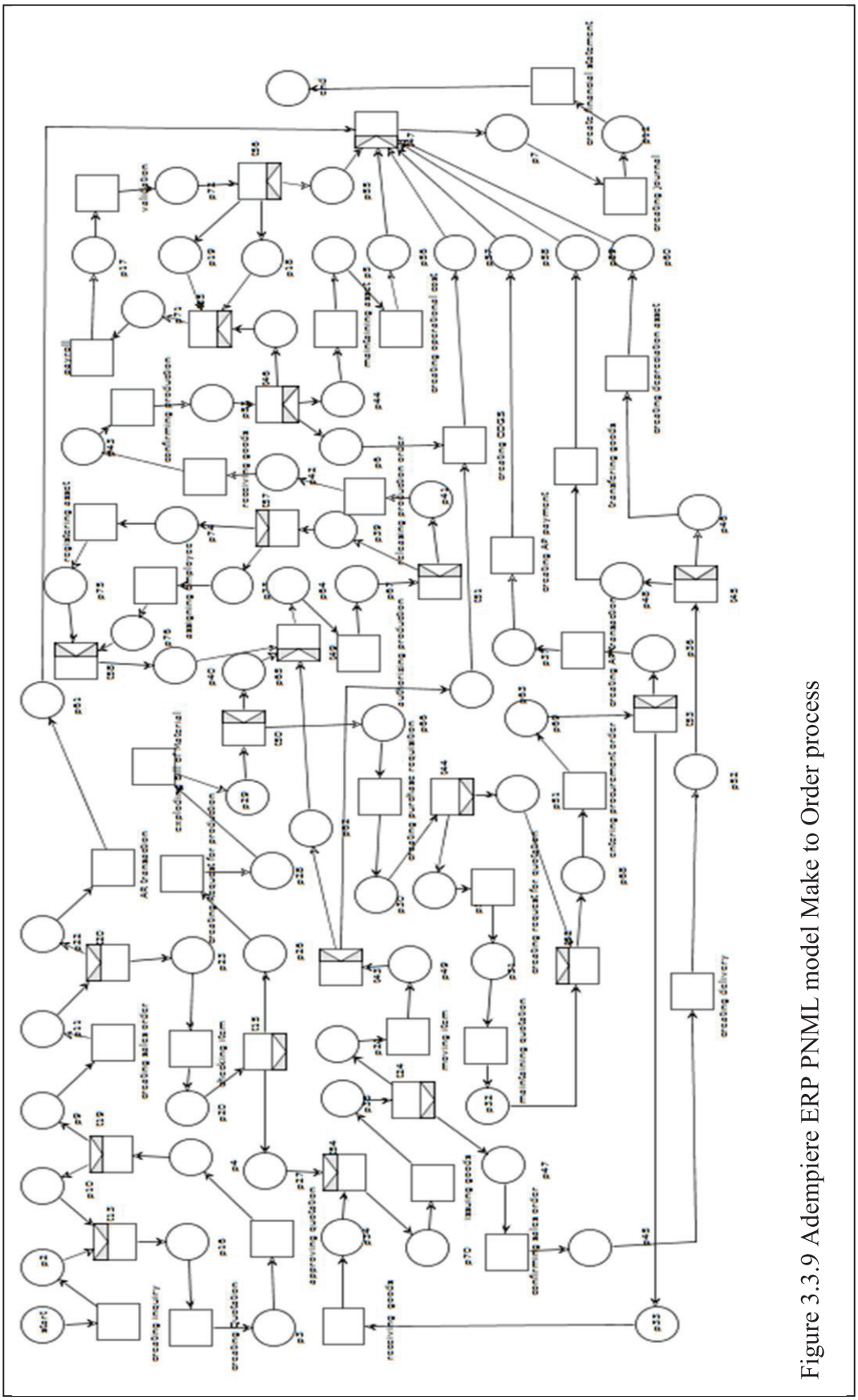


Figure 3.3.9 Adempiere ERP PNML model Make to Order process

- For interview with experts
  - Find weight of each variables in ISO 25022
  - Default inputs for Scale Factors Values set to nominal or fair and other cost drivers those cannot be measured without further research. At the moment it will be given a default value.
  - Prepare Questionnaire and mind the time of interview. Should not be more than 30 minutes.
  - Design data gathering
    - Interview – face to face
    - Convenience sampling – snowball method can be combine. Ask for reference of other expert who might be qualified to be the expert.
    - 4 ERP experts profiling:
      - ✓ IT programmer (intermediate with experience in programming over 2 years)
      - ✓ They have work with open-source ERP for at least 100 hours
      - ✓ They understand how to use COCOMO II

3.4 Conduct Interview

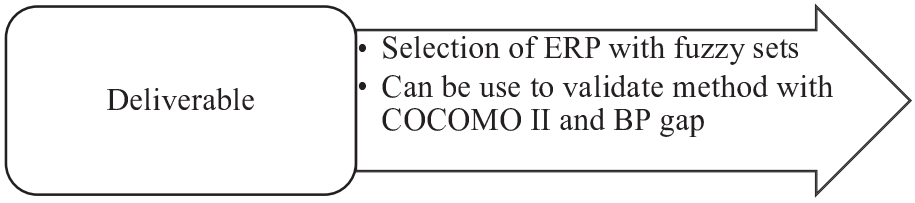
- Prepare questions with the four section. This question will be asked to the 4 experts. Follow the proper etiquette, be respectful and flexible.
  - Introduction
    - Name
    - Purpose to do research
    - Collect the participants data
    - Explain the template
    - Separate all four participants in space or time
    - Provide them help at their convenience if there is a question
  - Profiling
    - This is done to see the level of expertise at this area
    - Their experience in IT and hours involve in building it matters

Table 3.4.1 Decision Makers' Profile

Profile	D1	D2	D3	D4
Programming	C, html5, javascript, C++,PHP, Phython, ajax	C,C++,PHP ,SQL, C#, MATLAB, Python	C,C++,PHP,S QL,C#,MATL AB, Python	C, html5, javascript, C++,PHP, Phython, ajax
Experience in bulding software	3 years	4 Years	4 Years	4 years
# of Projects handled in IT	10-15	5	8	15-20
Years involved in ERP project	1.5 years	1 year	1 year	1.5 years
Utilize ERP (weekly basis)	35-40 hours per week	50-60 hours	42-50 hours	35-40 hours per week
Utilize ERP (yearly basis)	2000 hours per year	3000 hours per year	2500 hours per year	2000 hours per year
Develop ERP	4 months	4 months	4 month	4 months

- Question
- Thank you note and gift

- The result will be an input to the next steps.



3.5 Calculate, Analyze, Proof method

- METHOD: Fuzzy MCDM with experts for weighting criteria and valuing the systems. In comparison to Fuzzy MCDM with BP similarity as input combine with the experts weights

- Below are the tables that need to be fill out by the experts.
  - These inputs will be used for two method. Fuzzy MCDM and the proposed method Fuzzy MCDM with BP similarity as the input.

Table 3.5.1 Sub-Criteria Measurement MCDM Acronyms

Parameter to ERP	**CODE**
Effectiveness measures	C_1
Efficiency measures	C_2
Satisfaction measures	C_3
Freedom from risk measures	C_4
Context coverage measures	C_5

Table 3.5.2 Significance level

		Vector				
Level of Significance		**a**	**b**	**c**	**d**	**Rating**
Very Important	**VI**	0.7	1	1	1	100%-70%
Important	**I**	0.5	0.7	0.7	1	100%-50%
Fair	**F**	0.2	0.5	0.5	0.8	80%-20%
Weak	**W**	0	0.3	0.3	0.5	50%-0%
Very Weak	**VW**	0	0	0	0.3	30%-0%

- The evaluation linguistic level of significance can be drawn as on *Figure 3.5.1*.
- This scale can be used for interpreting the margin of error. It will be explain further at the bottom.

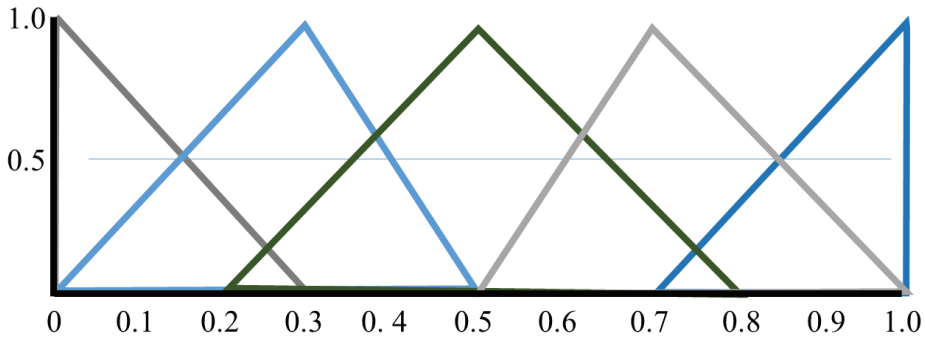


Figure 3.5.1 Fuzzy scale for weighting criteria

Table 3.5.3 Evaluation for each criterion

	D_1	D_2	D_3	D_4
C_1				
C_2				
C_3				
C_4				
C_5				

These section shows all the template that will be used for evaluation. The scale is adjusted already. Two fuzzy scale will be used. One to evaluate the criteria and the other to evaluate the alternatives

Table 3.5.4 Calculate each fuzzy vector a, b, c, and d for evaluating criteria weight according to four experts

a Lower bound=	D_1	D_2	D_3	D_4	Mean
C_1					
C_2					
C_3					
C_4					
C_5					

b Middle weight 1 =	D_1	D_2	D_3	D_4	Mean
C_1					
C_2					
C_3					
C_4					
C_5					

c Middle weight 2 =	D_1	D_2	D_3	D_4	Mean
C_1					
C_2					
C_3					
C_4					
C_5					

d Upper bound=	D_1	D_2	D_3	D_4	Mean
C_1					
C_2					
C_3					
C_4					
C_5					

Table 3.5.5 Expected output weight of criteria

	a	**b**	**c**	**d**
w_1				
w_2				
w_3				
w_4				
w_5				

Table 3.5.6 Linguistic Attributes for systems

Attributes		**Weight**			
		a	**b**	**c**	**d**
Very Bad	VB	0	0.1	0.1	0.2
Between Very Bad and Bad	BVB & B	0.1	0.2	0.2	0.3
Bad	B	0.2	0.3	0.3	0.4
Between Bad and Fair	BB & F	0.3	0.4	0.4	0.5
Fair	F	0.4	0.5	0.5	0.6
Between Fair and Good	BF & G	0.5	0.6	0.6	0.7
Good	G	0.6	0.7	0.7	0.8
Between Good and Very Good	BG &VG	0.7	0.8	0.8	0.9
Very Good	VG	0.8	0.9	0.9	1

- The linguistic attributes of the system can be drawn as on *Figure 3.5.2*

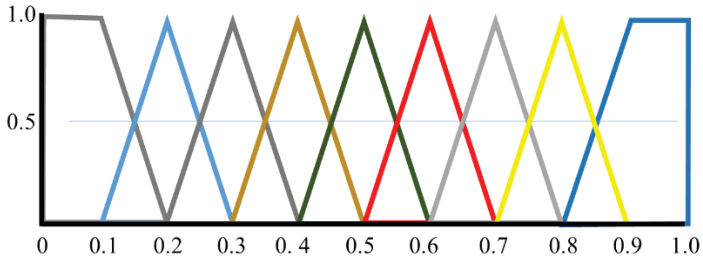


Figure 3.5.2 Fuzzy scale for evaluating system

Table 3.5.7 Evaluation ERP 1, 2, and 3

	D_1	D_2	D_3	D_4
C_1				
C_2				
C_3				
C_4				
C_5				

Fuzzy measurement for each criteria need to be customized. There will be scale for Criteria importance, then alternatives preference. The fuzzy scale is different from weighting the criteria. The same table to calculate the vector and same average formula calculation is done for *Table 3.5.8*. At *Table 3.5.10* the scoring and ranking begin.

Table 3.5.8 Calculate each fuzzy vector a, b, c, and d for evaluating system alternatives score according to four experts

a Lower bound=	D_1	D_2	D_3	Mean
S_1C_1				
S_1C_2				
S_1C_3				
S_1C_4				
S_1C_5				

b Middle weight 1 =	D_1	D_2	D_3	Mean
S_1C_1				
S_1C_2				
S_1C_3				
S_1C_4				
S_1C_5				

c Middle weight 2 =	D_1	D_2	D_3	Mean
S_1C_1				
S_1C_2				
S_1C_3				
S_1C_4				
S_1C_5				

d Upper bound=	D_1	D_2	D_3	Mean
S_1C_1				
S_1C_2				
S_1C_3				
S_1C_4				
S_1C_5				

Table 3.5.9 Final Classification System 1, 2, and 3

	a	**b**	**c**	**d**
S_1C_1				
S_1C_2				
S_1C_3				
S_1C_4				
S_1C_5				

- Final classification of every criteria is taken from the average of all decision makers' evaluation.

Table 3.5.10 Output table of each System 1, 2, and 3

	a	**b**	**C**	**d**	Sum
S_1C_1					
S_1C_2					
S_1C_3					
S_1C_4					
S_1C_5					
				SCORE	Sum of all mean

- S_1C_1 Vector a = (Classification S_1C_1 Vector a) * (w_1 Vector a) / (Total number of Criteria)
- Sum of all means will give the score for the system
- Do the same for all the systems and input all of the results on the score table below

Table 3.5.11 Final score of all alternatives

SYSTEM	SCORE
INO ERP	
ODOO ERP	
ADEMPIERE ERP	

- The highest rank based on the highest score will be chosen as the best alternative for the company
- The next step is conducting the BP similarity ERP selection.
- It will go through the same steps. However, the input will be the BP similarity results

Table 3.5.12 Similarity acronyms

Similarity	**Symbol**
Textual	SM1
Structural	SM2
Behaviour	SM3

Table 3.5.13 Output table of BP similarity calculation

	A1	A2	A3
SM1			
SM2			
SM3			

Weight

	A1	A2	A3
SM1			
SM2			
SM3			
TOTAL			

Weight

	A1	A2	A3
SM2			
SM3			
TOTAL			

The similarity percentage will be used as input to the table of measurement *Table 3.5.18* to replace experts' manual evaluation of each system.

- So in with this method the experts still involve to set weight of criteria. The weight of the SM1-SM3 is from the experts. They could take an estimation based on their experience. Simple electre tri method will be used

Table 3.5.14 BP Similarity after adjusted

Similarity	**A1**	**A2**	**A3**
Textual	18.5%	11.5%	25.2%
Structural	8.6%	4.6%	31.9%
Behavioural	18.1%	15.3%	27.8%
TOTAL	**45.2%**	**31.4%**	**84.9%**

Table 3.5.15 Acronym of COCOMO II cost drivers

Product Factors	Required Software Reliability	RELY	CD1
	Data Base Size	DATA	CD2
	Product Complexity	CPLX	CD3
	Required Reusability	RUSE	CD4
	Documentation match to life-cycle needs	DOCU	CD5
Platform Factors	Execution Time Constraint	TIME	CD6
	Main Storage Constraint	STOR	CD7
	Platform Volatility	PVOL	CD8
Personnel Factors	Analyst Capability	ACAP	CD9
	Programmer Capability	PCAP	CD10
	Applications Experience	PCON	CD11
	Platform Experience	APEX	CD12
	Language and Tool Experience	PLEX	CD13
	Personnel Continuity	LTEX	CD14
Project Factors	Use of Software Tools	TOOL	CD15
	Multisite Development	SITE	CD16
	Required Development Schedule	SCED	CD17

Table 3.5.16 Fuzzy scale to convert Similarity calculation and ROI

Attributes		**Weight**			
		a	**b**	**c**	**d**
Very Bad	VB	0	0.1	0.1	0.2
Between Very Bad and Bad	BVV & B	0.1	0.2	0.2	0.3
Bad	B	0.2	0.3	0.3	0.4
Between Bad and Fair	BB & F	0.3	0.4	0.4	0.5
Fair	F	0.4	0.5	0.5	0.6
Between Fair and Good	BF & G	0.5	0.6	0.6	0.7
Good	G	0.6	0.7	0.7	0.8
Between Good and Very Good	BG &VG	0.7	0.8	0.8	0.9
Very Good	VG	0.8	0.9	0.9	1

Table 3.5.17 Descriptor of the Similarity result and ROI

Attributes		SM1	SM2 & SM3			ROI
		C1	C2	C3	C5	C4
Very Bad	VB	0%	0%	0%	0%	0%
Between Very Bad and Bad	BVV & B	10%	10%	10%	10%	5%
Bad	B	20%	20%	20%	20%	10%
Between Bad and Fair	BB & F	30%	30%	30%	30%	15%
Fair	F	40%	40%	40%	40%	20%
Between Fair and Good	BF & G	50%	50%	50%	50%	25%
Good	G	60%	60%	60%	60%	50%
Between Good and Very Good	BG &VG	70%	70%	70%	70%	75%
Very Good	VG	90%	90%	90%	90%	100%

- The percentage distributed equally. Further research can focus on this instead of the integration. The descriptor of the similarity table is a test. The C4 descriptor is still subjective based on experts' definition of VB to VG Return of Investment.
- Use the COCOMO II guidelines for finding all effort multiplier
- Search the Customization code needed
- Input it into the software
- Calculated the ROI and fuzzify it.
- Input the evaluation based on the board

Table 3.5.18 Measurement table to convert BP similarity percentage for cost drivers in COCOMO II

Attributes		CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8	CD9	CD10	CD11	CD12	CD13	CD14	CD15	CD16	CD17
		SM1 SM2 SM3	SM1 SM2 SM3	DEF-AULT	SM2 SM3	SM1	DEFAULT											
		C4																
Very Low	VL	90%	90%		0%	0%												
		70%	70%		10%	10%												
Low	L	60%	60%		20%	20%										L	L	
		50%	50%		30%	30%												
Nominal	N	40%	40%		40%	40%		N	N	N	N	N		N	N			
		30%	30%		50%	50%												
High	H	20%	20%		60%	60%							H					H
Very High	VH	10%	10%		70%	70%	VH											
Extremely High	EH	0%	0%	EH	90%	90%												

Table 3.5.19 Scale Drivers of COCOMO II

Attributes		PREC	FLEX	RESL	TEAM	PMAT
		C4				
Very Low	VL					
Low	L					
Nominal	N	N	N	N	N	N
High	H					
Very High	VH					
Extremely High	EH					

Table 3.5.20 Output from evaluation of each system

COST DRIVERS		INO			ODOO			ADEMPIERE		
		EFFORT MULTIPLIER		SIM	EFFORT MULTIPLIER		SIM	EFFORT MULTIPLIER		SIM
CD1	**RELY**									
CD2	**DATA**									
CD4	**RUSE**									
CD5	**DOCU**									

Table 3.5.21 Output table of the calculation for each system

	A1
C_1	
C_2	
C_3	
C_4	
C_5	

- Calculate it the same way as the old method
- At the end it will be recorded in the same manner as the old system.

Table 3.5.22 Score table for the result of the proposed method

SYSTEM	SCORE
INO ERP	
ODOO ERP	
ADEMPIERE ERP	

- The result will be compared and discussed
- It is expected to give the same alternatives with the highest rank

Table 3.5.23 Margin of Error Old vs. Proposed Method

SYSTEM	SCORE		Margin of Error
	Fuzzy set method (old)	BP similarity method (proposed)	
INO ERP			
ODOO ERP			
ADEMPIERE ERP			

3.6 Create Report

- Documenting process and revise previous work or report
- Proposal
  - First draft: Chapter 1-3 in bullet points
  - Second draft: Chapter 1-2 is written
  - Final: 1-3 is written according to the required format.
- Findings or Discussion. It is expected to more precise than the previous work. Expert judgement will be used to confirm.
- Get supervisors and other people to read
- Fix final formatting with supervisor approval
- Create journal for conference according to the their requirement
- Take any feedback and edit for the final copy
- Printout in English with the expected MMT format

3.7 Research Schedule Plan

Below is the schedule of this research.

Table 3.6.1 Planned research schedule

Phases	2015								2016																							
	NOV				DEC				JAN				FEB				MAR				APR				MAY				JUN				JUL			
# of week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Formulating Idea																																				
Decide an Area																																				
Figure out a topic																																				
Formulating issue																																				
Proposal																																				
Literature Study																																				
Retrieve data																																				
1st draft																																				
2nd draft																																				
Validate method																																				
Create Questionnaire																																				
Gather weight for fuzzy																																				
Analyze																																				
Write Final Report																																				
Present proposal																																				
Seminar																																				
Rewrite																																				
Submit																																				
Present																																				
Thesis																																				
Write Final Report																																				
Review, edit, & format																																				
Presentation: Thesis																																				
Yudisium																																				

CHAPTER IV
RESEARCH RESULT

This chapter breakdown the steps of how the research being conducted. Steps taken are put in vertical process for easy understanding. Some of the outputs are presented.

4.1 Result

Both methods selected Adempiere, the third alternative, as the most suitable system. Both method select the last ERP based on the highest score and the highest rank. However, the margin of errors of the proposed method were 33% up to 62.4% lower than the first method. Nevertheless, the experiment was a success.

Table 4.1.1 Result of Both method and Margin of error

SYSTEM	SCORE		Margin of Error
	Fuzzy set method (old)	BP similarity method (proposed)	
INO ERP	2.186875	0.822	62.4%
ODOO ERP	1.70725	0.654	61.7%
ADEMPIERE ERP	2.484625	1.664	33.0%

The Margin of error percentage means represent specific level of significance based on the fuzzy scale on *Figure 3.5.1* which was also planned to be used to interpret margin error. Below is the scale, it is defuzzifying using the Saaty scale.

The third alternative error is 33%, between fair and weak. The other two alternatives are 61.7% and 62.4%, important. The margin of error of both method comparison is concerning. However, because the margin of error can be justified. The proposed method could be more reliable due to

the cost estimation method. Both method should be compared to the scoring after implementation which can be done for future work.

Table 4.1.2 Scale for Interpreting Margin Error

Scale for Interpreting Margin of Error	
Saaty scale	**Level of Significance**
80.1 – 100%	Extremely Important
70.1 – 80%	Very Important
60.1 – 70%	Important
50.1 – 60%	Between Fair and Important
40.1 – 50%	Fair
30.1 – 40%	Between Fair and Weak
20.1 – 30%	Weak
10.1 – 20%	Very Weak
0 – 10%	Extremely Weak

Below will describe further the steps to get to the final result on *Table 4.1.1*.

4.1.1 Result of sorting criteria

This sorting is needed that will lead out to filtering the parameter and give guidance to giving the criteria weight. They are rank according to the importance of the parameters to the success of ERP *Table 2.12.1*. This scale is used thorough the layers of parameters or criteria.

Table 4.1.3 Ranking the criteria

CODE	Parameter to ERP	D1	D2	D3	D4	AVERAGE	RANK
C1	Effectiveness measures	9	9	9	9	**9**	1
C2	Efficiency measures	8	8	7	8	7.75	5
C3	Satisfaction measures	7	8	8	9	8	4
C4	Freedom from risk measures	9	9	9	9	9	2
C5	Context coverage measures	8	8	9	9	**8.5**	3

Since it is a top down approach, the sub-criteria is ranked after the criteria ranked. Only the one with average score of 8 will be filtered out to validate the sub-sub-criteria ranking based on pareto rule. It is a rule that believes, 80% of the effect comes from the top 20% of the factor (Juran, M. J., 1964).

Table 4.1.4 Ranking the Sub criteria

CODE	Parameter to ERP	D1	D2	D3	D4	Mean	RANK
SC1	Effectiveness measures	9	8	9	9	**8.75**	1
SC2	Efficiency measures	8	7	9	8	**8**	5
SC3	Usefulness measures	9	8	8	8	**8.25**	3
SC4	Trust measures	7	7	8	7	7.25	
SC5	Pleasure measures	7	7	7	6	6.75	
SC6	Comfort measures	7	6	7	6	6.5	
SC7	Risk mitigation measures	7	7	8	7	7.25	
SC8	Financial measures	9	8	9	9	**8.75**	2
SC9	Health and safety measures	6	6	7	7	6.5	
SC10	Environmental measures	6	6	7	6	6.25	
SC11	Context completeness measures	7	7	7	8	7.25	
SC12	Flexibility measures	8	8	9	8	**8.25**	4

The filtered result of Table 4.1.4 on Table 4.1.5 supports Table 4.1.3 based on importance to the success of ERP according to the experts.

Table 4.1.5 Filtered Sub-criteria

CODE	Parameter to ERP	RANK
SC1	Effectiveness measures	1
SC8	Financial measures	2
SC5	Usefulness measures	3
SC12	Flexibility measures	4
SC2	Efficiency measures	5

The critical parameter sorted on Table 4.1.8 support the sub-criteria on Table 4.1.5 :

- Effectiveness only have one sub-criteria. Based on *Table 4.1.6* the task effectiveness is more important before the completion nor the error frequency.
- In Freedom from risk measures, the financial measures is the most important parameter. Based on the table below the breakeven point and other financial measures can be measured with Return of Investment. It also calculated probability of default risk.
- For satisfaction measures, the usefulness measures is the most important. Usefulness is important measurement for satisfaction. It is depends on the functionalities fulfillment. It is almost similar to the effectiveness.
- As for context coverage, the flexibility or reusability is the important one.
- Ultimately, efficiency is the last measurement user will contemplate at the beginning of the selection. Economic productivity is used to measure.

Further research can evaluate all or the unexplored measurement. The sorting and filter phase is necessary to ensure that this research able to finish within the intended time and more focus.

The next table is ranking the top 20% of the sub-sub criteria or the sub-criteria parameter. Some parameters will require other parameters as an input. The pre-requisite parameters will be selected as the research parameter. This sorting method is electre-tri method, explain on chapter 2. Simply using the four decision maker to evaluate the criteria. Then calculate the average.

Table 4.1.6 Ranking Sub-Sub Criteria or Measurement

CODE	Parameter to ERP	D1	D2	D3	D4	Mean	RANK
SSC1	Task completion	8	7	8	8	7.75	
SSC2	Task effectiveness	9	8	9	9	**8.75**	1
SSC3	Error frequency	5	7	7	7	6.5	
SSC4	Time efficiency	8	7	7	7	7.25	
SSC5	Relative task time	7	5	6	6	6	
SSC6	Task efficiency	7	5	6	8	6.5	
SSC7	Relative task efficiency	7	6	5	7	6.25	
SSC8	Economic productivity	8	7	9	9	**8.25**	4
SSC9	Productive proportion	8	8	8	8	**8**	8
SSC10	Relative number of user actions	7	8	7	7	7.25	
SSC11	Satisfaction scale	7	8	8	9	**8**	9
SSC12	Satisfaction questionnaire	8	8	7	8	7.75	
SSC13	Discretionary usage	7	8	7	8	7.5	
SSC14	Discretionary utilization of functions	7	6	7	8	7	
SSC15	Proportion of Customer complaints	7	8	7	8	7.5	
SSC16	Trust scale	7	6	6	7	6.5	
SSC17	Pleasure scale	7	9	8	7	7.75	
SSC18	Comfort scale	6	8	8	6	7	
SSC19	Risk mitigation	8	8	8	8	**8**	10
SSC20	Return of investment (ROI)	9	8	8	9	**8.5**	2
SSC21	Time to achieve a return of investment	9	8	8	9	**8.5**	3
SSC22	Relative business performance	7	8	7	8	7.5	
SSC23	Balance Score Card	8	8	7	8	7.75	
SSC24	Delivery time	8	7	7	9	7.75	
SSC25	Missing items	8	8	8	8	**8**	11
SSC26	Revenue for each customer	8	8	9	8	**8.25**	5
SSC27	Errors with economic consequences	9	7	9	8	**8.25**	6
SSC28	Software corruption	9	8	8	8	**8.25**	7
SSC29	User health and safety frequency	7	6	6	6	6.25	
SSC30	User health and safety impact	6	5	5	6	5.5	
SSC31	Safety of people affected by use of the system	6	5	6	6	5.75	
SSC32	Environmental impact	5	4	5	3	4.25	
SSC33	Complex completeness	8	7	8	8	**7.75**	
SSC34	Flexible context of use	8	8	7	9	8	12
SSC35	Flexible design features	8	9	8	7	**8**	13

Table 4.1.7 Critical Parameter Sorted

CODE	CRITICAL Parameter to ERP	RANK
SSC2	Task effectiveness	1
SSC8	Economic productivity	2
SSC20	Return of investment (ROI)	3
SSC21	*Time to achieve a return of investment*	4
SSC26	*Revenue for each customer*	5
SSC27	*Errors with economic consequences*	6
SSC28	*Software corruption*	7
SSC9	*Productive proportion*	8
SSC11	Satisfaction scale	9
SSC19	*Risk mitigation*	10
SSC25	*Missing items*	11
SSC34	Flexible context of use	12
SSC35	*Flexible design features*	13

Table 4.1.8 Critical Parameter summarized

CODE	CRITICAL Parameter to ERP	RANK
SSC2	Task effectiveness	1
SSC8	Economic productivity	2
SSC20	Return of investment (ROI)	3
SSC11	Satisfaction scale	9
SSC34	Flexible context of use	12

The Table *4.1.6* filtered out the very important parameter to the success of ERP and the result is on Table *4.1.7*. It is then simplified or filtered to Table *4.1.8* based on the origin of the parameter. Parameters on Table *4.1.7* needs measurement in Table *4.1.8* to begin with.

4.1.2 Result fuzzy set MCDM Method

Below is the same criteria used to evaluate the system as the fuzzy set method and the proposed method

Table 4.1.9 Criteria for the proposed method as in ISO 25022

Parameter to ERP	CODE
Effectiveness measures	C_1
Efficiency measures	C_2
Satisfaction measures	C_3
Freedom from risk measures	C_4
Context coverage measures	C_5

Table 4.1.10 Criteria weights evaluation

	D_1	**D_2**	**D_3**	**D_4**
C_1	VI	VI	VI	VI
C_2	F	I	I	I
C_3	I	I	I	VI
C_4	VI	I	VI	VI
C_5	VI	I	I	VI

Linguistic attributes are used to increase relevancy. The lowest evaluation marked is fair. It is justified since all criteria are critical parameter to the success of ERP. This evaluation will be defuzzify as shown on the table below and multiply by the system evaluation after defuzzified as well.

Table 4.1.11 Criteria weight Evaluation Defuzzification

a Lower bound=	**D_1**	**D_2**	**D_3**	**D_4**	**Mean**
C_1	0.7	0.7	0.7	0.7	0.7
C_2	0.2	0.5	0.5	0.5	0.425
C_3	0.5	0.5	0.5	0.7	0.55
C_4	0.7	0.5	0.7	0.7	0.65
C_5	0.7	0.5	0.5	0.7	0.6

b Middle weight 1 =	D_1	D_2	D_3	D_4	Mean
C_1	1	1	1	1	1
C_2	0.5	0.7	0.7	0.7	0.65
C_3	0.7	0.7	0.7	1	0.775
C_4	1	0.7	1	1	0.925
C_5	1	0.7	0.7	1	0.85

c Middle weight 2 =	D_1	D_2	D_3	D_4	Mean
C_1	1	1	1	1	1
C_2	0.5	0.7	0.7	0.7	0.65
C_3	0.7	0.7	0.7	1	0.775
C_4	1	0.7	1	1	0.925
C_5	1	0.7	0.7	1	0.85

d Upper bound=	D_1	D_2	D_3	D_4	Mean
C_1	1	1	1	1	1
C_2	0.8	1	1	1	0.95
C_3	1	1	1	1	1
C_4	1	1	1	1	1
C_5	1	1	1	1	1

Table 4.1.12 Criteria weight evaluation result

	a	b	c	d
w_1	0.7	1	1	1
w_2	0.425	0.65	0.65	0.95
w_3	0.55	0.775	0.775	1
w_4	0.65	0.925	0.925	1
w_5	0.6	0.85	0.85	1

Above is the result of defuzzify criteria weight from the experts criteria evaluations. This will be used by both method, the fuzzy sets and the proposed. The next step is to evaluate the alternatives. This paper only show one of the alternative evaluation.

Table 4.1.13 ERP System 1 Alternatives Evaluation method 1

	D_1	D_2	D_3	D_4
C_1	G	BG &VG	BG &VG	BG &VG
C_2	BF & G	G	BF & G	BF & G
C_3	G	BF & G	BF & G	BF & G
C_4	BG &VG	BF & G	BF & G	BF & G
C_5	G	F	BF & G	BF & G

Above is the experts' evaluation on Ino ERP based on the five criteria.

Table 4.1.14 ERP System 1 Alternatives Evaluation method 1 Defuzzification

a Lower bound=	D_1	D_2	D_3	D_4	Mean
S_1C_1	0.6	0.7	0.7	0.7	0.675
S_1C_2	0.5	0.6	0.5	0.5	0.525
S_1C_3	0.6	0.5	0.5	0.5	0.525
S_1C_4	0.7	0.5	0.5	0.5	0.55
S_1C_5	0.6	0.4	0.5	0.5	0.5
b Middle weight 1 =	D_1	D_2	D_3	D_4	
S_1C_1	0.7	0.8	0.8	0.8	0.775
S_1C_2	0.6	0.7	0.6	0.6	0.625
S_1C_3	0.7	0.6	0.6	0.6	0.625
S_1C_4	0.8	0.6	0.6	0.6	0.65
S_1C_5	0.7	0.5	0.6	0.6	0.6
c Middle weight 2 =	D_1	D_2	D_3	D_4	
S_1C_1	0.7	0.8	0.8	0.8	0.775
S_1C_2	0.6	0.7	0.6	0.6	0.625
S_1C_3	0.7	0.6	0.6	0.6	0.625
S_1C_4	0.8	0.6	0.6	0.6	0.65
S_1C_5	0.7	0.5	0.6	0.6	0.6
d Upper bound=	D_1	D_2	D_3	D_4	
S_1C_1	0.8	0.9	0.9	0.9	0.875
S_1C_2	0.7	0.8	0.7	0.7	0.725
S_1C_3	0.8	0.7	0.7	0.7	0.725
S_1C_4	0.9	0.7	0.7	0.7	0.75
S_1C_5	0.8	0.6	0.7	0.7	0.7

Table 4.1.15 FINAL EVALUATION SYSTEM 1 method 1

	a	**b**	**c**	**d**
S_1C_1	0.675	0.775	0.775	0.875
S_1C_2	0.525	0.625	0.625	0.725
S_1C_3	0.525	0.625	0.625	0.725
S_1C_4	0.55	0.65	0.65	0.75
S_1C_5	0.5	0.6	0.6	0.7

Table 4.1.16 Ranking the System 1 method 1

	a	**b**	**c**	**d**	
S_1C_1	0.0945	0.155	0.155	0.175	0.5795
S_1C_2	0.044625	0.08125	0.08125	0.13775	0.344875
S_1C_3	0.05775	0.096875	0.096875	0.145	0.3965
S_1C_4	0.0715	0.12025	0.12025	0.15	0.462
S_1C_5	0.06	0.102	0.102	0.14	0.404
					2.186875

- The calculation is quite simple as mentioned on chapter 2.
- S_1C_1 Vector a = (Classification S_1C_1 Vector a) * (w_1 Vector a) / (Total number of Criteria)

Table 4.1.17 Result of the evaluation using Fuzzy set method

SYSTEM	SCORE
INO ERP	2.186875
ODOO ERP	1.70725
ADEMPIERE ERP	2.484625

Adempiere ERP is selected based on the highest score. Second is the Ino ERP as the second highest. Last is Odoo due to the lack of completeness in its modules which represent effectiveness.

4.1.3 Result Proposed MCDM Method

This section will show step 1 to 5 as planned. Only the first alternative evaluation will be shown.

Step 1: Calculate BP Similarity

a) Business Process similarity in textual

Table 4.1.18 Textual similarity of requirement to alternatives

No	Requirement	INO	ODOO	ADEMPIERE
1	exploding master routing	0	0	0
2	confirming sales order	0	0	0
3	creating AR payment	0	0	0
4	authorizing production	0	0	1
5	planning resources	1	0	1
6	creating depreciation asset	0	0	1
7	exploding Bill of Material	0	0	1
8	transferring goods	0	0	1
9	approving quotation	0	0	1
10	creating Request for production	1	0	0
11	validation	0	0	1
12	creating AR transaction	0	0	1
13	creating AP transaction	0	0	1
14	confirming production	0	1	1
15	receiving goods	1	0	1
16	creating purchase requisition	1	0	1
17	creating request for quotation	1	0	1
18	checking item	1	0	1
19	issuing goods	1	0	1
20	start	1	1	1
21	creating sales order	1	1	1
22	creating Quotation	1	1	1
23	maintaining asset	1	1	1
24	create financial statement	1	1	1
25	end	1	1	1
26	creating journal	1	1	1
27	creating purchase order	1	1	1
28	create COGS	0.632	0	0
29	assign employee	0.787	0	1
30	receive good	0.920	0.862	1
31	*deliver order*	0.787	0.785	0.785
32	create AP payment	0.985	0.999	1
33	*move item*	0.862	0.822	0.883
34	*release production order*	0.986	0.998	0.996
35	*human payroll*	0.691	0.372	0.564
36	*maintain customer*	0.364	0.388	0
37	create inquiry	0.839	0	1
	Average	**61.77%**	**38.45%**	**83.97%**

b) Structural and behavioural Similarity

Table 4.1.19 Business Process similarity in structural and behavioural

Similarity Methods	Comparison of Business Requirement to ERP alternatives		
	InoERP	OdooERP	Adempiere
Jaccard structure	0.21447028	0.114583336	0.7973422
BTS	0.3	0.1	1

Step 2: Calculate the technical sub-criteria

Table 4.1.20 Parameter for Similarity

Parameter to SIMILARITY	CODE
Textual	SM1
Structural	SM2
Behaviour	SM3

Table 4.1.21 Result of BP Similarity

	A1	A2	A3
SM1	61.77%	38.45%	83.97%
SM2	21.45%	11.46%	79.73%
SM3	60.27%	51.08%	92.70%

Table 4.1.22 Adjusted Similarity with weight of all or only SM2 with SM3

Weight		A1	A2	A3
30%	SM1	18.5%	11.5%	25.2%
40%	SM2	8.6%	4.6%	31.9%
30%	SM3	18.1%	15.3%	27.8%
	TOTAL	45.2%	31.4%	84.9%

weight		A1	A2	A3
55%	SM2	11.8%	6.3%	43.9%
45%	SM3	27.1%	23.0%	41.7%
	TOTAL	38.9%	29.3%	85.6%

Table 4.1.23 BP Similarities and ROI as System Evaluation

Code	A1	A2	A3
C_1	G	BB & F	BG &VG
C_2	B	B	BG &VG
C_3	B	B	BG &VG
C_4	VB	VB	BB & F
C_5	B	B	BG &VG

- This process went through a process of fuzzification.

Step 3: Estimating cost of customization

Table 4.1.24 Conversion Result of Similarity to Cost Driver Effort Multiplier for COCOMO II

COST DRIVERS		INO			ODOO			ADEMPIERE		
		EFFORT MULTIPLIER		SIM	EFFORT MULTIPLIER		SIM	EFFORT MULTIPLIER		SIM
CD1	**RELY**	**Nominal**	**1.00**	45.2%	**High**	**1.10**	31.4%	**Low**	**0.92**	84.9%
CD2	**DATA**	**Nominal**	**1.00**	45.2%	**High**	**1.14**	31.4%	**Low**	**0.90**	84.9%
CD4	**RUSE**	**Nominal**	**1.00**	38.9%	**Low**	**0.95**	29.3%	**Very High**	**1.15**	85.6%
CD5	**DOCU**	**High**	**1.11**	61.77%	**Nominal**	**1.00**	38.45%	**Very High**	**1.23**	83.97%

Table 4.1.25 KLOC needed for System 1, 2, and 3 customization

	REQUIRED	inoERP	Odoo	Adempiere
Line Of Code	5,000,000.00	408,789.00	913,263.00	4,727,170.00
KLOC	5,000.00	408.79	913.26	4,727.17
KLOC needed		**4,591.21**	**4,086.74**	**272.83**

The Table 4.1.24 and Table 4.1.25 will be the input to calculate cost.

Step 4: Calculate ROI

The ROI is calculated by assuming that the benefit of adopting the right system will save the company $100,000 per month for all the 26 locations.

Table 4.1.26 Calculated Cost and ROI for all alternatives

	inoERP	Odoo	Adempiere
Effort (person-month)	79946.3	77877.2	3783
Schedule (months)	123.9	122.9	45.3
Cost (Dollar)	$ 159,892,617.00	$ 155,754,314.00	$ 7,566,046.00
ROI (per year)	**0.751%**	**0.770%**	**15.860%**
BEP (years)	133.24	129.80	6.31

Step 5: Selection

Table 4.1.27 EVALUATION FOR ERP System 1 method 2

CODE	**A1**	**A2**	**A3**
C_1	G	BB & F	BG &VG
C_2	B	B	BG &VG
C_3	B	B	BG &VG
C_4	VB	VB	BB & F
C_5	B	B	BG &VG

This process is done for the other alternatives. Once the evaluation is done it will be fuzzified and will go through the same process as fuzzy set method. Then it will be fuzzified as in the first method.

Table 4.1.28 Calculation of A1 Defuzzification Method 2

a Lower bound=	D_1	Calculation
S_1C_1	0.6	0.6
S_1C_2	0.2	0.2
S_1C_3	0.2	0.2
S_1C_4	0	0
S_1C_5	0.2	0.2

b Middle weight 1 =	D_1	
S_1C_1	0.7	0.7
S_1C_2	0.3	0.3
S_1C_3	0.3	0.3
S_1C_4	0.1	0.1
S_1C_5	0.3	0.3

c Middle weight 2 =	D_1	
S_1C_1	0.7	0.7
S_1C_2	0.3	0.3
S_1C_3	0.3	0.3
S_1C_4	0.1	0.1
S_1C_5	0.3	0.3

d Upper bound=	D_1	
S_1C_1	0.8	0.8
S_1C_2	0.4	0.4
S_1C_3	0.4	0.4
S_1C_4	0.2	0.2
S_1C_5	0.4	0.4

Table 4.1.29 FINAL EVALUATION SYSTEM 1 method 2

	a	**b**	**c**	**d**
S_1C_1	0.6	0.7	0.7	0.8
S_1C_2	0.2	0.3	0.3	0.4
S_1C_3	0.2	0.3	0.3	0.4
S_1C_4	0	0.1	0.1	0.2
S_1C_5	0.2	0.3	0.3	0.4

After all the evaluation is defuzzified. They will be scored and ranked, as the fuzzy set method. The company XYZ will select system based on the highest rank.

Table 4.1.30 Ranking the System 1 method 2

	a	b	c	d	
S_1C_1	0.084	0.098	0.098	0.112	0.392
S_1C_2	0.017	0.0255	0.0255	0.034	0.102
S_1C_3	0.022	0.033	0.033	0.044	0.132
S_1C_4	0	0.013	0.013	0.026	0.052
S_1C_5	0.024	0.036	0.036	0.048	0.144
				SCORE	**0.822**

Table 4.1.31 Result of the evaluation using BP similarity method

SYSTEM	SCORE	RANK
INO ERP	0.822	2
ODOO ERP	0.654	3
ADEMPIERE ERP	1.664	1

4.2 Findings

This section will analyze the similarity and the difference of both method.

4.2.1 Findings Proposed Method vs. Old method

At this phase of research, the Business process similarity can gives a vague idea the amount of work for customization. The scope of work still also depends on the other 13 cost drivers which is not part of the scope. Basically, the result shows that the proposed method is effective and can be used to select out of hundreds of alternatives model.

The result of the second method is not exactly the same score as the fuzzy set method. Few major causes that might have influence the result:

- First cause is the cost of customization. At the end both of ERP acquisition is still more expensive. However since the customization cost is considered as an important value. The second method became more realistic. Customization in ERP fitting is a critical matter. Not just picking the system because the vendor popularity. Combining

COCOMO II strengthening the ISO 25022 financial risk criteria. The estimated output become more accurate. Further research needed for integrating the BP similarity to COCOMO II cost drivers.

- Second is the complexity or behaviour of the structure is picked up at the second method where the expert might have missed it with the firat method and only focus on the completeness. The business process similarity is one of the approach that evaluate the system technicallity. Further BP similarity method needs to be researched. Accuracy can be increased through the BP models drawn. Broader scope of business process and deeper level of process can increase reliability in proposed method.
- Last, is the best method of integrating the BP similarity, scoring, and COCOMO II. This research main purpose is to prove that it is possible to integrate all method to become a selection method.

4.3 Discussion of the finding

The benefit of the difference and the impact toward business performance. Dissect the weakness or flaw of the proposed method based on the findings.

4.3.1 Discussion

The appropriate ERP system that meet the business requirements based on the functional and financial criteria of ISO 25022 according to both methods is the third alternative. Based on the effectiveness, it has most of the modules needed. It is the most effeciency that fulfilled the required standard. Adempiere ERP satisfied most of the documents, reusability, and functions that the user look for. The second method evaluate that the freedom from risk measured such as financial risk is lower than the expert. This is due to the different estimation methods used. The first method highly depend on the experts experience is customization in all three modules.

The second method, able to measure four cost drives out of the seventeen cost drivers which represent scope of work for customization by measuring business process gap. A descriptor is needed to fuzzify the similarity result linguistic attributes. It is not accurate table yet but can be researched further as it is critical part to the score result.

ERP selection based on several expert preferences use the fuzzy set method. It is also relying on the expert presents to evaluate the system. It might be inconvenience if they have to evaluate more than hundreds of alternatives.

Pro:

- Less dependency on experts at alternatives evaluation
- Fitting the system precisely as the required
- The financial risk is fully paid attention. Using the COCOMO II is better than the experts' estimation to calculate the customization cost.
- The behaviour of the system is known and matched
- The completeness of the system is quantified.
- More reliable since the fitting is based on quantitative

Contra:

- Still need the expert to decide on the criteria preference.
- More work for vendor or user to provide BP models
- Definitely take more time and effort
- Method to calculate BP similarity has not been perfected
- There are other consideration that are left out or not counted yet such as the 13 cost drivers
- Have to draw its BP requirement and the alternatives to fit. The deeper the level of drawing the more reliable the results are to be used.
- Affected by many factors (criteria weights, similarity accuracy, or COCOMO approach)

- Scales and measurements are distributed equally. Further research might be needed.
- Integration Scale or Descriptor for fuzzification distributed equally among the values and it needs to be researched
- Only the Make to Order process is evaluated.

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CHAPTER V
RESEARCH CONCLUSION

This chapter is a synthesis of information that had been discussed in the earlier chapters.

5.1 Conclusions

Successful experiment because it selected the same alternatives. The other purposes of this study of ERP selection method are also fulfilled.

First, selecting the right system will increase the likelihood of successful ERP implementation at company XYZ. The study is expected to develop a method for selecting a system that is suitable for the business and select the same alternatives as the fuzzy set method. However, it is not resulted the same score. If the first method is correct then it can be used as reliable benchmark. Then the second method is not as accurate as the predicament.

Second purpose, integrate business similarity as inputs to COCOMO II four cost drivers and other four criteria of ISO 25022. Integrate successfully with equal distribution on the measurement values.

Third, proposed a method that is simple and eliminate ambiguity of the expert evaluation. The second method eliminate the expert evaluation on each system. Further development into automatic selection could be a possibility.

Last, combine one of the criteria financial measures of the ISO/IEC 25022 criteria with COCOMO II will be able to give a better result of selection and more precise estimation of cost.

5.2 Recommendation

Several improvisation that can be done:

- improve BP Similarity methods and weighting in textual, structural, and behavioural;
- adjustment for integration measurement scale to fuzzify the similarity results;

- use more alternatives not only open-source and tested on more models;
- use models that are on level 2 ERP to detect the complex behaviour of the BP that is not within this research scope;
- the data more than a 30 of past ERP selections should be ideal;
- experts who has more experience in customization on all alternatives.

5.2.1 Future work

Future works that can improve this study are:

- as recommended use non open-source ERP;
- more valid *Business Process data* from the vendors if it is accessible;
- using statistic approach from bigger data sample to analyze that all variables from ISO 25022 and COCOMO II are validated;
- analyze the relationship between variables how it is influencing each others;
- consider *Business Process Reengineering* (BPR) and *Business Process Management* (BPM) into the integration;
- broader business process not just the make to order process;
- deeper activities on level 2 and 3 of ERP can be researched;
- include complexity of workflow within the research;
- integration measurement scale for Similarity and COCOMO II distributed accordingly to the significance;
- as for COCOMO II, the worker are set at minimum wage $2000 per person per month and the maintenance is not counted. This is done for the purposed of controlled environment as the research should minimized any variables;
- lastly, BP similarity best method can be studied and which cost drivers of COCOMO II can be affected.

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