AN EXPLORATORY CASE STUDY ON THE REQUIREMENTS BUSINESS PROCESSES OF A TYPICAL SOUTH AFRICAN HIGH TECHNOLOGY SYSTEMS ENGINEERING COMPANY

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Abstract: This article describes the findings of an exploratory case study into the requirements management and engineering processes of a South African Systems Engineering Company and how these processes affect the business of the company. For the purpose of this article the name of the company is kept confidential. This case study identifies processes that resulted in both successful and unsuccessful project performance, reasons for the problems, successful processes and ideas for practice improvement. The findings illustrate which processes are used, why requirement processes are important, and provide useful insights on causes of project failure and situations to be avoided. The findings also show where the main focus for company improvement should lie. This case study culminates in recommendations on ways to improve the current requirements processes of the company and proposes a theory on the use of requirements management and requirements engineering processes in the company.

Keywords: Requirements Management; Requirements; Systems Engineering; Business Process Improvement.

Abbreviations:
CMM – Capability Maturity Model
INCOSE – International Council of Systems Engineering
SEI – Software Engineering Institute

1. INTRODUCTION

Numerous actions exist on operational and strategic level which South African Systems Engineering and Defence Companies can use to improve their competitiveness. One of these actions is the effective use of requirements management and requirements engineering processes (also referred to as 'requirements development' by the Software Engineering Institute [SEI] [1]. There are various definitions for 'requirements management' and 'requirements engineering', some of which can be found in published literature as illustrated in Table 1.

The primary research objective of this paper is to determine the use of requirements management and requirements engineering processes in the company, and to determine what effect these processes have on project performance. The secondary research objectives are to identify actions and procedures that can be implemented to improve requirements management and engineering efficiency in project execution; identify requirements causes for unsuccessful project performance; and identify areas for improvement in current requirements management and requirements engineering processes. All these processes are critical to the success of the company's primary business, which is the execution of projects that involve creating complex systems for clients.

The importance of requirements management and requirements engineering is illustrated a number of published sources. On the Software Engineering Institute website, as well as in [2], it is stated that the single biggest problem of building software is to determine what to build, or in other words to define the software requirements. Sommerville [3] also notes this problem and describes requirements engineering as focusing in particular on describing the solution. According to Hood *et al* [4] requirements engineering is accomplished by the requirements definition process. Requirements management and requirements engineering is therefore identified in literature as major areas for process improvement [3]. Brooks [2], Damian, Chisan, Vaidyanathasamy and Pal [5], however, report that there is a need to measure the effect of requirements engineering processes to determine its effectiveness. The Standish Report details that the average number of projects completed on time and within budget improved from 16.2% in 1995 (only 9% for large organisations) [6] to 34% in 2003 [7]. One of the main causes of unsuccessful projects highlighted in both studies is unstable requirements. The 2009 chaos report shows a slight decrease in the percentage of successful projects from 34% to 32% [8]. A study by Hall, Beecham and Rainer [9] indicates that 48% of development problems were caused by requirements problems. Jones [10] identifies project management problems related to requirements. These are the rejection of accurate cost, schedule and technical estimates (*relates to effective*

requirements engineering), the failure to use automated estimation and planning tools, an excessive irrational schedule definition (*relates to effective requirements engineering*), and the user requirements scope creep (*relates to effective requirements management*). To further illustrate the importance of accurate requirement, the International Council of Systems Engineering (INCOSE) handbook indicates that, based on studies done in the United States, during the concept and definition phase where requirements are established, 8% of the project LCC (Life Cycle Cost) is used up, but up to 80% of the system cost is determined by decisions made [11].

Table 1: Definitions of requirements management and requirements engineering

Term	Definition
Requirements management	The interface between requirements development and all other systems engineering disciplines, including configuration management and project management [4].
	Capability Maturity Model (CMM) v1.2: 'requirements management' [1]: "*manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project plans and work products*".
Requirements engineering	Consists of requirements definition, from customer requirements to product requirements and product component requirements [4].
	CMM v1.2: 'requirements development' (also known as requirements engineering) [1]: "*the purpose of requirements development is to produce and analyse customer, product and product component requirements*".

The software and defence industry has responded to the abovementioned problems by creating various process models. These models include the Software Engineering Institute [SEI] Capability Maturity Model [1], International Standards Organisation [ISO] 15288 [12], ISO 12207 [13] and many others. INCOSE created a website of requirements engineering best processes that allows anyone to contribute processes [14]. Damian *et al* [5] noted three predominant requirements engineering process improvement frameworks; these are the CMM, the ISO 15504 [15] and the Sommerville and Sawyer [16] model. Paulk, Curtis, Crissis and Weber [17] lists the benefits of the CMM model as productivity related benefits including cost decreases; improved agreement among team members regarding designs and; more accurate project cost and schedule estimates. Unfortunately there is little empirical evidence in published literature that prove the benefits of the requirements engineering and management process frameworks. Even with these models requirements management and requirements engineering comprise a relatively new field which lacks well established measurement metrics and research data. Most of the practical guides to requirements management and engineering such as those presented in Sommerville and Sawyer [16] and Robertson and Robertson [18] offer only generic requirements processes.

2. MATERIALS AND METHODS

2.1 Previous requirements process improvements

Damian *et al* [5] carried out a case study and documented empirical evidence on the project performance of improved requirements processes and the positive effects thereof on downstream software development in the Australian Company of Unisys Systems (ACUS). The results of the case study conducted by Damian *et al* [5] concluded that the process activities which had the most significant effect on project performance were: collaborating cross functional team involvement resulting in better designs; numerous analysis and requirements review sessions that exposed design flaws and; and real-world (scenario based) test descriptions which meant that systems are tested in the same way that they are used. Faily [19] detailed a case study of improving requirements engineering processes within the European Space Agency Flight Dynamics Division.

Zainol and Mansoor [20] conducted a survey of the requirements management processes and implementation of CMM level 2 activities in the Malaysian software industry. Verner and Cerpa [21] reused the same survey questions as Verner and Evanco [22] to investigate the requirements management processes of Australian software companies. In another study by Verner and Evanco [22] the authors detail the results of a survey into requirements engineering processes, where interviews were conducted with 21 software professionals regarding one successful and one unsuccessful project. In a study by Cox, Niazi and Verner [23] the researchers determined the most useful requirements management processes implemented by surveyed Australian software companies. As basis for the identified processes the authors used the 66 requirements processes identified by Sommerville and Sawyer [16]. In their study Lodhi, Tariq, Naveed, Gul and Khalid [24] identified the requirements engineering best processes used in the Pakistan software industry. Yuclacar and Erdogan[25] evaluated the CMMI level 2 maturity of five Turkish software companies. The study used 39 research questions from all the CMMI process areas (requirements management, project planning, project monitoring and control, supplier agreement management, measurement and analysis, project and quality awareness, and configuration management), including three questions from the requirements management process area. Groves, Nickson, Reeve, Reeves and Utting [26] surveyed selected New Zealand software companies using a questionnaire and in-depth interviews focusing on requirements gathering. Cuevas, Serrano Alan and Serrano Ariel [27] developed a method to access the requirements management processes of a company using a two stage questionnaire based upon the CMM [1]. The authors selected among numerous research questionnaires to evaluate the most accurate

questionnaire. The options were the *CMM-Based Appraisal for Internal Process Improvement* (*CBA IPI*) V1.1 [28], Northup Grumman Process Improvement Model and the Institute for Software Process Improvement [IISP] [29].

2.2 Research background

The origins of this research lay in the first author's new role of business analyst within the defence industry, a role that had previously been available only within the commercial/banking industry. In order to fulfil this role the author needed to determine the requirements problem areas and the causes for these problems. Moreover, it has been speculated that the use of requirements management and requirements engineering processes by South African Systems Engineering Companies may be poor, if not non-existent, and that requirements management and requirements engineering have a definite effect on project performance.

This research is important for the following reasons: It will indicate the maturity of the requirements management processes within a South African Systems Engineering and Defence company; allow for a comparison with the requirements management and engineering processes used in other companies; identify areas of requirements management and engineering improvement; add to the (currently) scant empirical evidence on the effect of requirements management and engineering in spite of a considerable body of literature emphasising the benefits; and identify process changes that resulted in improved project performance. The conceptual investigation methods are given in Table 2.

Table 2: Conceptual investigation method per research proposition

#	Research propositions	Conceptual investigation methods
1	There are specific requirements engineering processes that either increase or decrease the likelihood of successful project completion.	Determine which requirements engineering factors most affect successful project outcome and which most significantly affect failed project outcome.
2	The company does not implement requirements management processes.	Determine which requirements management processes are used within the company.
3	The company does not implement requirements engineering best processes.	Determine a list of requirements engineering best processes and detail which of the processes are used within the company.
4	There are major requirements factors affecting project failure.	Identify the major requirements problems experienced on projects and their impact.
5	There are requirements engineering factors that significantly affect project success.	Identify the major requirements successful action that increased project quality and the impact of each.
6	Improvements can be identified.	Identify the major requirements improvement ideas and the importance of each.

2.3 Research methodology

Yin [30] proposes the use of an exploratory case study method when exploring a new field where little is known. Four sources of evidence (listed in Table **3**) are used in order to probe deeply to gain a better understanding of the requirements management and requirements engineering processes used by the company and the effects thereof.

There is a single unit of analysis which is the company. The chosen sample is the system engineers of the company. Sampling used non probability sampling, which, as described by Merriam [31], is appropriate for qualitative research questions similar to those used in this research.

Table 3: Sources of evidence and research method

Source of evidence	Detail of implementation
Survey	• A survey was created reusing the yes/no questions of Verner and Cerpa [22], Zainol and Mansoor [20] and best practice descriptions on the REGAL website [14]. • To ensure validity the survey was reviewed by a senior systems engineer (20+ years' experience) • Experienced senior systems engineers were identified and asked to complete a survey over a period of two months from approximately May to July 2010.
Interviews	• An open-ended and semi-structured interview, lasting approximately one hour, was conducted with the identified systems engineers (the same systems engineers who were surveyed). • The interviews were recorded in short hand notes and analysed for patterns in response. • The interviewees were informed that all company, client, person and projects names are kept confidential. • The interviews focused on one successful and one unsuccessful project that the systems engineer

Source of evidence	Detail of implementation
	was involved in as well as on company requirements processes.
Documentation analysis	• Identify and analyse the project documentation for the successful and unsuccessful projects mentioned by the system engineers. • Only the projects that were conducted within the company could be analysed. • Documents are analysed based on evaluation criteria described later in this article.
Personal (direct) observations	• Company structure and overview • Brief project overview

3. RESULTS

The company used for this research develops electronic warfare products which are incorporated into electronic warfare systems for clients. The company has approximately 30 years of experience and employs 250 people with an approximately R 500m yearly turnover. The company follows a formal systems engineering process model in executing projects. Figure 1 shows the company departments and their interaction.

The product development department is responsible for developing new products based on product specifications. These products, sometimes incorporated into systems, are sold by the Marketing department. Once a system is contracted it is the responsibility of the system engineering department to deliver the completed system. The system engineering department is supported by the Production department, which manufactures industrialised products, and the software department which implements the interfaces between products as well as developing the user interfaces. Once systems are completed the delivered systems are supported by the Logistics department during renewable support contracts. For each system delivered within a project the systems engineering department creates a formal system specification and in response, while the software department creates the software specification.

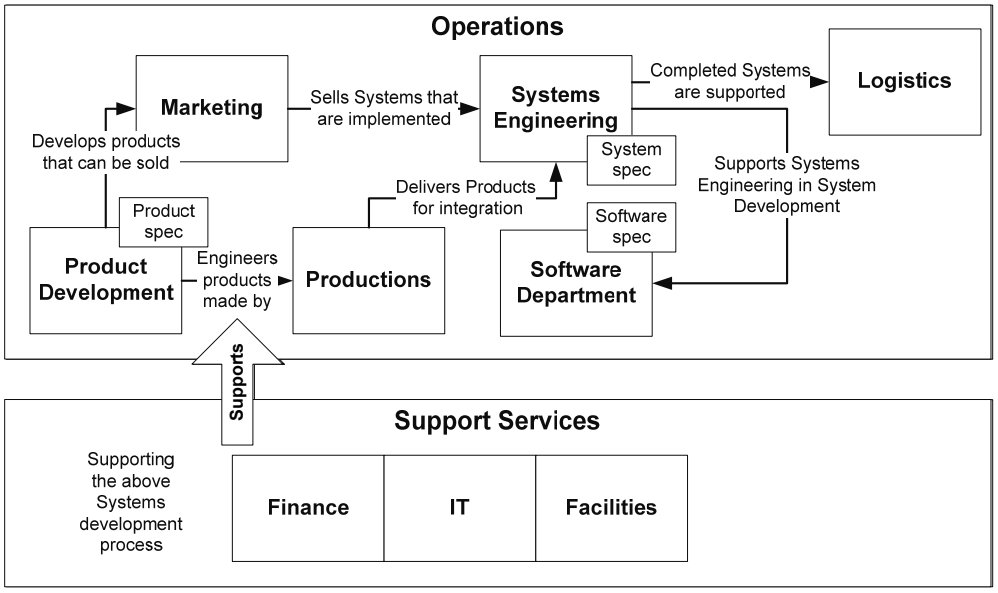

Figure 1: Company business process overview

3.1 Survey results

Figure 2 indicates survey results of which requirements engineering factor most influences project success. The results show that in successful projects, 6) requirements change is very small and that the 3) accurate requirements at the PDR stage, 4) overall clear and accurate requirements and 8) requirements fulfilling client expectations are the factors that most significantly influence project success. Eight survey responses were received (this represents 70% of the systems engineers in the company).

Figure 3 indicates the survey results of which requirements engineering factors most influences project failure. The results indicate that, for failed projects, three factors influence project failure the most. These are 6) Significant project scope change, 3) Accurate and complete requirements at the PDR stage and 4) Overall clear and accurate requirements. Eight survey responses were received (this represents 70% of the systems engineers in the company).

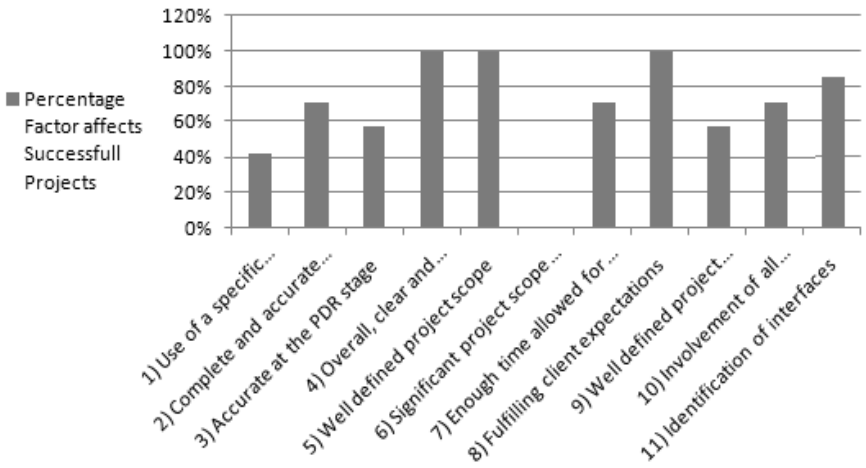

Figure 2: Successful Project Requirements Engineering Factors

Table 4 illustrates the survey results of which requirements management processes are implemented in the company. Eight survey responses were received (this represents 70% of the systems engineers in the company). The results of Table 4 illustrate that of all the requirements management processes 61% are implemented in the company. No modelling, either with UML or SysML, is used to describe requirements and no requirement prototypes are built. Another interesting result is that the company does not have any requirements management guidelines and does not record deleted/rejected requirements.

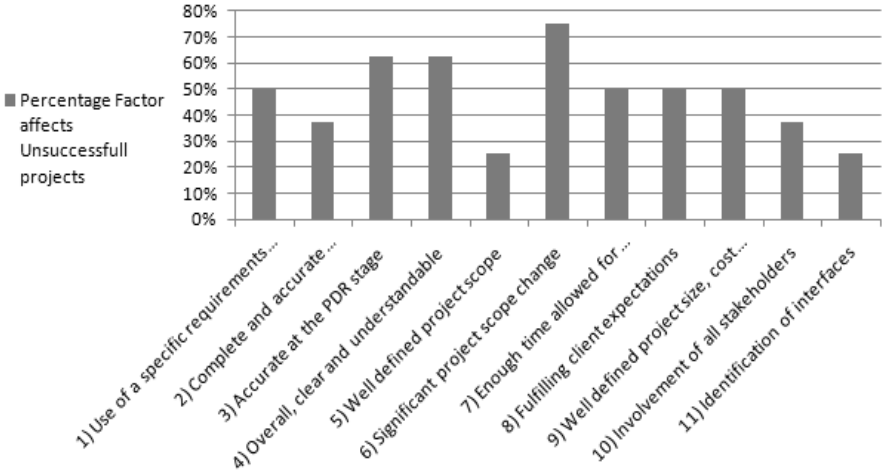

Figure 3: Unsuccessful project requirements engineering factors

Table 4: Usage of requirements management processes

Requirements management practice		**Used**
a.	Do you have standards / templates / documents / tools for describing requirements?	Y
b.	Do you have guidelines on how to write requirements?	Y
c.	Do you use the UML (Unified Modelling Language) to document requirements?	N
d.	Do you use the SysML (Systems Modelling Language) to document requirements?	N
e.	Do you supplement the written requirements with diagram descriptions?	Y
f.	Do you specify requirements with unique identification?	Y
g.	Do you develop a prototype in order to understand poor or complex requirements?	N
h.	Do you re-use requirements from other similar systems?	Y
i.	Do the requirements show the system boundaries?	Y
j.	Do you develop a checklist for requirement analysis?	Y
k.	Do you perform a specific requirements analysis process with a specified output?	N
l.	Do you prioritise requirements?	Y

Requirements management practice		Used
m.	Do you perform any risk analysis on requirements?	Y
n.	Do you use prototyping to demonstrate requirements for validation?	N
o.	Do you have defined policies for requirements management?	N
p.	Do you use a central repository database or requirements management tool?	Y
q.	If you answered yes to the previous question, which one do you use? **No / In-house tool**	
r.	Do you identify risky (cost, schedule or quality - TPM) requirements?	Y
s.	Do you record rejected requirements?	N

The results of Table 5 illustrate the survey results of which requirements engineering best processes are implemented in the Company. Eight survey responses were received (this represents 70% of the systems engineers in the company).

Table 5: Usage of requirements engineering best processes

Best practice		Never	Infrequent	Mostly	Always
3.1	Define a standard document structure for requirements	13%	25%	63%	0%
3.2	Define new products in terms of deltas on existing products	0%	13%	75%	13%
3.3	Ensure that every requirement is quantified	25%	13%	63%	0%
3.4	Establish a verification statement for requirements	25%	25%	50%	0%
3.5	Identify the type of requirements flow-down	13%	50%	38%	0%
3.6	Make use of requirements classification, sorting and filtering	38%	63%	0%	0%
3.7	Propose trade off options against requirements	0%	38%	63%	0%
3.8	Ensure that interface requirements are complete	13%	13%	63%	13%
3.9	Ensure that one and only one requirement in each statement	0%	13%	63%	25%
3.10	Use a simple language to express requirement	0%	13%	75%	13%
3.11	Define Product Scope	0%	13%	88%	0%
3.12	Define the system context	0%	25%	63%	13%
3.13	Document the system goals as part of scope	0%	63%	25%	13%
3.14	Identify relevant stakeholders	0%	50%	38%	13%
3.15	Focus on the problem to be solved	0%	50%	38%	13%
3.16	Identify requirements using scenarios	0%	50%	50%	0%
3.17	Identify the goal of a requirement	0%	0%	100	0%
3.18	Negative scenarios to elaborate non-functional requirements	25%	75%	0%	0%
3.19	Understand the need for the system	0%	0%	75%	25%
3.20	Verify requirements using operational models / scenarios	0%	25%	63%	13%

The results in Table 5 shows that none of the requirements best processes are used on any of the projects, but that 14 of the 20 (70%) best processes are mostly used while six of the 20 (30%) best processes are used infrequently. The survey results from the eight respondents who also indicate that negative scenarios are not used, requirements flow-down traceability is only completed infrequently and system goals are not always defined.

3.2 Interview results

The interview results describing ideas for requirements process improvement are presented in Table 6. The importance value is determined by the number of respondents mentioning the idea and the importance the respondents attached to the idea.

Table 6: Ideas for improvement to company's requirements engineering processes

Improvement idea	Interview feedback	Importance
Conduct BIA on new clients	Three respondents suggested conducting a Business Information Analysis (BIA) on new clients. The purpose is to document the existing client work processes and existing client information definition and data structures.	Low
Multi-disciplined scoping team	Two respondents expressed the idea of using a multi-disciplined team, each with different roles to perform initial project scoping and requirements analysis for complex projects.	Medium
Bid / no-Bid checklist	A suggestion was made by two respondents to use a checklist to ensure that production capacity is taken into account and that Technical risks are identified	Medium

Improvement idea	Interview feedback	Importance
	during the bidding process.	
Product owners input at bid / no-Bid meetings	One respondent highlighted that product owners should be present at bid / no-bid meetings to ensure that technical risk is taken into account.	High
	A need was expressed by all respondents for more accurate technical input into the marketing process to perform requirements analysis.	
	A need was identified by one respondent for the adequate assessment of what is possible with current technologies and future technologies.	
	All respondents highlighted the risk of marketers performing high-level system design without technical inputs.	
Risk budget	Two respondents expressed the need to increase the risk budget allocation on projects.	Medium
	This was also highlighted by a third respondent who stated that the existing budgets on previous systems were inadequate.	
Obsolescence problem	One respondent highlighted that obsolescence of product / product components is not part of the bid process.	Low

The most important new idea highlighted in Table 6 was for the inclusion of technical product owners in the marketing process to perform requirement analysis and system scoping. Table 7 indicates the requirements problems, identified by the respondents, affecting projects. The occurrence value is determined by the number of respondents who mentioned the factor and the impact the respondents thought implementing the factor would have.

Table 7: Most significant requirements problems affecting projects

Factor	Interview feedback	Occurrence
Unrealistic systems sold	All respondents mentioned the problems experienced when marketing sells a system that is not realistic or achievable.	High
New product development during project execution	Three respondents highlighted the risk of having a large component of new development within a project and the use of projects to industrialise products.	Medium
	Two different respondents respectively mentioned projects where significant project development was done during the execution of a project, resulting in one case a seven year (80% new development) and in another case a three year schedule overrun (50% new development and complex product integration).	
Unrealistic requirements	Two respondents highlighted the effect of one unsuccessful project where a proper requirements analysis was only done after four years.	Low
Understand client expectation	Three respondents highlighted that one of the contributing factors to the unsuccessful project was that the requirements were not understood and accurately captured in a specification document.	Low
Negotiation difficulty	Four of the respondents identified negotiation difficulty was making a significant contribution to un-successful projects.	High
	In another instance the relationship with the client was not based upon trust and this meant that accurate requirements analysis could not be performed during project scoping.	
Production capacity	One respondent suggested that production capacity must be taken into consideration during the bidding process	Medium

Table **7** indicates that negotiation difficulty problems and unrealistic systems designed during the marketing process as the main problems that occur most often in projects.

3.3 Document analysis results

In Table 8 it is indicated that the project characteristics and the project document analysis results. For confidentiality purposes the projects are numbered A to N. The documentation of the projects mentioned by respondents was analysed.

Table 8: Project characteristics

#	Project	Complexity	Experience	Negotiation
1.	A	High	High	Difficult
2.	B	Average	H	Difficult
3.	C	Small	Very High	Easy
4.	D	Average	Low	Easy
5.	E	High	High	Not Applicable
6.	F	Small	Low	Easy

#	Project	Complexity	Experience	Negotiation
7.	G	Small	High	Difficult
8.	H	High	High	Difficult
9.	I	High	High	Difficult
10.	J	High	Very High	Easy
11.	K	High	High	Difficult
12.	L	High	High	Difficult
13.	M	High	High	Difficult
14.	N	?	?	?
? – external project about which no information is known				

Table 9: Results of document analysis

Yes (Y) No (N)	Successful projects								Unsuccessful projects					
Document characteristic	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
a. Documentation agrees with systems eng. process	Y	Y	Y	Y	Y	Y	N	Y	-	Y	-	N	N	-
b. System engineering tailoring	N	N	N	N	N	N	N	N	-	N	-	N	N	-
c. System specification	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	-	Y	N	-
c. Software specification	Y	Y	Y	Y	Y	Y	N	Y	-	Y	-	N	N	-
e. Traceability system and software requirements	N	N	N	N	N	N	N	N	-	N	-	N	N	-
f. Requirements analysis	Y	Y	Y	Y	Y	Y	N	Y	-	Y	-	N	N	-
g. Unique identified requirements	Y	Y	N	Y	Y	N	N	Y	-	Y	-	Y	Y	-
h. Systems verification criteria	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	-	N	Y	-
i. Software verification criteria	N	Y	N	Y	Y	N	N	N	-	Y	-	N	N	-

Table 9 indicates that tailoring of the systems engineering process was not done and that even through specifications for both software and systems are drawn up, no traceability analysis is completed. Successful projects contrasts to unsuccessful projects by the systems engineering process followed and the definition of software specifications.

An industrialising investigation was completed in 2007 by an external consultant. The contents of the industrialisation investigation report were analysed to determine and identify any correlation with interviews and survey results (see Table **10**)

Table 10: Feedback from industrialisation report

Department	Description
Marketing	The industrialisation report notes three causes of problems experienced in project execution. These are that the company never says no to a deal; sells un-industrialised products, and that no measure of the production capacity is taken into account when contracting new systems.
Product development	The main problem is that products are not industrialised which, according to the report, is caused by under staffing and technical and administrative short cuts.
Software development	The problems expressed in the industrialisation report is that the software department is overloaded and understaffed and that the department is required to handle a number of parallel projects causing too much rework and quality problems.

3.4 Personal observation results

Table 10 as well as in the problems described during interviews from Table 7 can be understood as follows: due to current processes the marketing department sells un-industrialised products. This increases the workload of the product department to industrialise new products because of rework on old products. The effect of always saying “yes” to projects is to overload the production capacity and the capacity of the software department due to too many parallel projects. The overload of the software and product department reduces the quality and increases the rework required. The negative feedback loop increases the load and reduces output even further resulting in more overruns and schedule delays for subsequent projects unless capacity is increased.

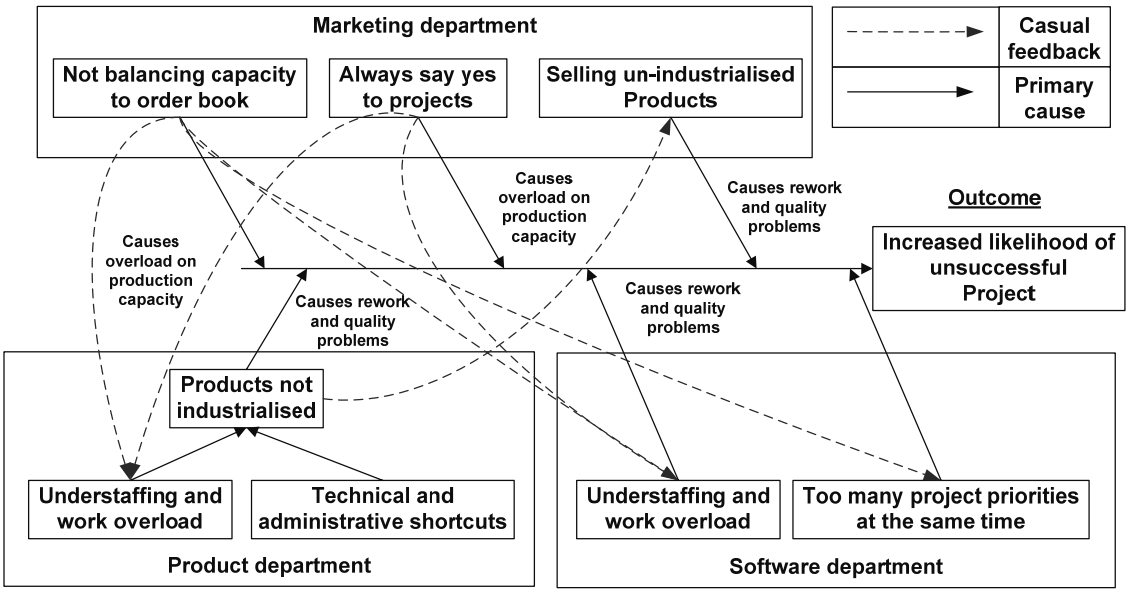

Figure 4: Fishbone diagram showing cause and effect between reported problems

Figure 4 can be understood as follows: due to current processes the marketing department sells un-industrialised products. This increases the workload of the product department to industrialise new products because of rework on old products. The effect of always saying "yes" to projects is to overload the production capacity and the capacity of the software department due to too many parallel projects. The overload of the software and product department reduces the quality and increases the rework required. The negative feedback loop increases the load and reduces output even further resulting in more overruns and schedule delays for subsequent projects unless capacity is increased.

4. DISCUSSION

4.1 Overview of results

The results of the survey into successful and unsuccessful requirements factors show that limited requirements scope change positively influences project success. This is expected due to the nature of the complex projects undertaken by the company. The results show that the respondents perceive significant changes to requirements to have large effect on the project cost and schedule. The results of the survey of requirements management processes indicate that the company performs more requirements management processes than what is usually done in the average Malaysian company [20]. This is expected due to the complex nature of the systems developed and the importance of requirements management for complex projects. The company's requirements engineering processes can be improved by using requirements modelling. The company implements 70% of the requirements best processes. Improvement can however be made by using requirements filtering and sorting, describing requirements using scenarios and implementing traceability (also called requirements flow-down).

Most respondents feel that technical experts should be included in the initial system design and that this design should be performed during the marketing/contracting phase of a system. This is identified as a definite area in which the company can improve. The interviews on factors influencing successful project outcome highlighted the importance of using the systems engineering process and the advantage gained from technical inputs into the marketing process. The two issues that caused the most significant problems on projects were the sale of unrealistic systems to clients and negotiation difficulty experienced with the clients. Investigations should be made on successful negotiation strategies.

The document analysis supports the findings that requirements traceability is not performed adequately in the company. This indicates that the systems engineering process was not followed. An analysis of the industrialisation report shows that the problem of selling systems that contain un-industrialised products with unrealistic requirements has been with the company for at least three years. This causes other problems further along in the project lifecycle as shown in Figure 4.

The company has a limited number of clients; the effect of this is that the company has developed a culture of always accepting client requests and selling systems that do not take current capacity into account. This has resulted in overload on current staff that decreases the quality of delivered systems.

4.2 Theory on the effect of requirements management in the company

The requirements practices and processes used in the company are determined by the requirements defined during the initial project definition and contracting phase.

Usually this is handled by marketing. The absence of business analyst involved during this process produces lower quality requirements. This increases project costs as well as increases the changes of project failure.

4.3 Business improvement recommendations

The recommendations to the company are grouped according to the specific process area.

Table 11: Business improvement recommendations

Process improvement area	Proposed actions
System design process	1. It is proposed that systems engineers should investigate the use of System Modelling Language (SysML) and Unified Modelling Language (UML) in systems modelling. 2. The company must standardise and define a standard process for requirements engineering and verification. The guidelines for acquiring and documenting the requirements detailed in [32] can be used as guidance.
System engineering process	3. It is proposed that a policy to encourage strict adherence to implementing requirements traceability should be instilled as a standard work practice with systems and software engineers. 4. It is recommended that all system engineers are educated in this process and that the process is standardised in the company. It is further recommended that the standardisation be coupled with tailoring guidance. 5. It is recommended that the systems engineering process should also be used to perform product development and money should be spent to educate more users on the benefits of using the systems engineering process.
Tender process	6. It is proposed that a tender committee checklist could help with this problem but maybe an even more aggressive approach needs to be taken.
Client communication	7. In the case of negotiation difficulty the following is proposed: investigate the client culture and define specific strategies to enable successful project negotiation. 8. There must be a larger initial focus on gaining client confidence by frequent client visits, joint work sessions, joint training sessions and BIA analysis.
Product industrialisation process	9. Review and improve the product industrialisation process by: a. considering current production capacity in project planning, negotiations and bidding on tenders; b. investigating the increase of production capacity; c. identifying and implementing actions that improve product quality output and; d. improving the use of systems engineering in product industrialisation.

4.4 Conclusion

In conclusion, the survey results indicate that the company does implement requirements management and requirements engineering processes. Therefore this is not the area on which focus should be placed first. The survey results also show that there are requirements factors that significantly contribute to a successful project outcome. These results corroborate what is already documented in published literature on the advantage of using these processes. The interview results highlight the effect that requirements management and requirements engineering processes have on project performance by showing the main problems experienced by system engineers, the successful processes used and ideas for improvement. It is interesting to note that the requirements management and requirements engineering processes, described in the survey, were not mentioned during interviews. The interview results focus mainly on the marketing department and improving requirements analysis during contracting. The document analysis showed the value of the systems engineering process. The advantage of this process was also strongly highlighted during interviews. The most important areas for improvement are:

- Product industrialisation &
- Client communication

4.5 Research limitations

The major limitation of this case study is that it did not include any quantitative project schedule and budget (project cost) information which could have revealed correlation between the monetary and time effect of the specific problems mentioned and requirements management and requirements engineering processes. In future research project cost and schedule data can be analysed to determine the effect of the problems mentioned. The implementation of new requirements processes and procedures could be quantitatively evaluated. Future research can focus on product industrialisation and client communication.

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