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BUSINESS CASES FOR PRODUCT CONFIGURATION SYSTEMS

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Abstract: *In the recent years, product configuration systems (PCSs) have received greater attention from industries providing customized products as a response to increased demand to fulfil diverse customers' needs for customized products. Before developing a PCS, a well-established business case has to be made in order to secure the success and delivery of the project as it will increase the commitment from the business side. This paper presents a framework for supporting the development of business cases for PCSs and discusses the experiences from multiple case studies benefiting from the suggested framework.*

Key Words: *Product Configuration System (PCS), Business Case, IT Projects*

from the beginning. There is strong literature foundation on business cases for IT projects in general. This paper summarizes the literature of business cases for IT projects in order to make business cases framework for PCSs specifically considering the similarities between IT and PCS projects. The proposed framework for generating business cases is then tested on three cases. Finally, the results from the case studies are discussed and further studies are elaborated. The main questions to be answered are:

1. What are the most important steps related to business cases in IT projects?
2. How to formulate, define different steps and introduce specific tools for business cases in PCS projects?

1. INTRODUCTION

Product configuration systems (PCSs) are used to support design activities throughout the customization process, where a set of components along with their connections are pre-defined and constrains are used to prevent infeasible configurations [1]. The growing product variety at the companies has led to an increasing complexity of products and processes and underlined the need of a better coordination in product specifications [2]. Investing in IT projects in industrial organizations raises the question: Whether the investment in the IT project has a positive impact on organizational productivity? Stratopoulos and Dehning [3] prove that successful investment in IT projects leads to improved financial performance. Shao and Lin [4–6] also claimed that IT has a positive effect on technical efficiency. There are some researchers who do not answer the question of IT economically, but from socio-technical perspective concerning the social and technical elements of change [7,8].

Investing time in identifying the benefits, expectations, financial needs and risks behind an IT project reduces the risks of the projects being abandoned later in the process. Since performing PCS projects is a complicated task [9,10] and involving number of stakeholders, it is difficult to anticipate the expectations and implementation costs beforehand.

To cope up with these challenges, there is a need for a more structured PCS project planning and implementation with a well-established business case

2. RESEARCH METHODOLOGY

The first phase of the research was devoted to select the most comprehensive business case foundation to build on for PCSs projects. The individual phases of the proposed framework were developed based on literature of business cases for IT projects. Furthermore, the authors' experiences from working with over 20 industrial partners on different PCSs projects were used in order to make the framework more comprehensive. The proposed framework was discussed and outlined through a period of 6 months.

The second phase of the research was devoted to test the framework. A project team was formed in the companies, which included researchers and employees from the companies. Two case companies were identified where the framework was tested on three projects in total. The case companies were chosen based on operating globally, providing highly engineered, complex products and in the process of implementing a PCSs to support the sales and engineering process. The companies operate in different industries where the former case company is an international company specialized in production of heterogeneous catalysts and in the design of process plants based on catalytic processes. The latter case company is in the construction industry where the aim is to support various aspect of the engineering process at the company with PCSs. The proposed framework for business cases in PCS projects was tested in order to test the individual steps of the framework and improve it based on feedback.

3. LITERATURE STUDY

3.1. Business cases for IT projects

The main reason for project failures can be explained in terms of lack of project planning and weak business cases [11]. Business case can be defined as "description of a situation or sequence of events confronting an individual, a set of individuals, or an organization and includes a detailed account of the events leading to the point in time at which the case concludes"[12].

In Table 1, different researchers introducing different constituent dimensions for business case methodology for IT projects in general are demonstrated.

Table 1. *Main elements of business cases in IT projects*

Researcher	Main elements of business cases in IT projects
Gambles [13]	1) Strategic fit, 2) Stakeholders' analysis, 3) Benefits mapping, 4) Cost modelling, 5) Risk analysis
Ashurst et al. [14]	1) IT gap analysis, 2) IT scenarios analysis, 3) Cost estimation
Hakknen and Hilmola [15]	1) Benefits analysis, 2) Stakeholders' analysis, 3) IT requirements and gap analysis, 4) Risk analysis
McNaughton et al. [16]	1) Benefits analysis and objectives, 2) Stakeholders' analysis, 3) IT requirements, 4) Cost modelling
Taylor et al. [7]	1) Stakeholders' analysis, 2) Technical requirement, 3) Cost modelling, 4) Risk management
Benlian [17]	1) Benefits analysis, 2) Stakeholder' requirement, 3) IT gap analysis, 4) IT scenarios analysis, 5) Risk analysis, 6) Cost estimation

As shown in the table above, there are multiple frameworks for business cases in IT projects, where there is overlap in the elements included in the frameworks. The main elements can be described in terms of: benefit analysis, stakeholder's analysis, IT requirements, and risk analysis. Based on the main elements, the differences and similarities between the IT projects and PCSs, the framework for PCSs business cases was developed. In the available literature for PCS projects, the mentioned steps details and tools are available, but a structured framework to relate all these steps is lacking. Software configuration management handles dependencies of software artefacts in the context of 'software development projects [18]. A major difference from software to configuration technologies can be explained by lack of an abstract, declarative model of the source code being configured [19].

4. FRAMEWORK DEVELOPMENT

Based on the available literature on IT projects and experiences of working with PCSs, the framework for making business cases for PCS projects was developed. Based on the similarities between IT and PCS projects, the main steps available in all frameworks for IT projects chose for PCS projects. On the other hand, based on the differences between IT and PCS projects, details and proposed tools for each of these steps are different. The framework is the result of the most possible comprehensive framework form IT projects while the

details of steps are specified for PCS projects. The individuals' steps of the framework are the following:
1. Goal setting and benefit analysis
2. Stakeholders' analysis
3. Process analysis, scenario making and gap analysis
4. Scenarios evaluation based on how they contribute to the initial goals including:
   - Cost-benefit analysis
   - Risk management

In the following sections, a further explanation of the individual steps of the framework are provided and supported with the relevant literature.

4.1. Goal setting and benefit analysis

The literature emphasizes on the various benefits gained by using PCSs in different organizational settings. The most common benefits can be listed in terms of: reduced lead time and resources consumption, higher quality of specification, higher independency from domain experts, better decision making in early phases of sales, accurate and free of errors quotations, less rework and higher customer satisfaction [2,20–24].

Based on the commonly described benefits the goals of the implementation have to be aligned with the current difficulties at the company and strategy. Identifying the goals and the desired benefits to be gained from the implementation of the PCS is highly important as it will provide guidelines for the following steps.

4.2. Stakeholder analysis

The main stakeholders' requirements identification helps in understanding of the project [25]. Use case diagrams are the means of expressing the requirements and the actors involved in the project [26].

There is literature both reflecting stakeholders' analysis in IT projects [27–30] and PCS projects [20,31–33]. For IT projects in general the categorization of requirements can be divided into two types of requirements: functional and non-functional. A requirement, which describes not what the software will do, but how the software will do it is called a non-functional requirement [27]. On the other hand, a functional requirement, which specifies each of the functions that a system must be capable of performing is defined as functional requirement [27]. MoSCoW rules can be beneficial when prioritizing the stakeholders' requirements based on: Must have (Mo), Should have (S), Could have (Co), and Want to have (W) requirements [30].

4.3. Process analysis, scenario making and gap analysis

The specification process at the company is analysed in order to get an overview of the most important activities, their sequences and connections, list up the persons responsible for the different activities, information flows and the processes' inputs/outputs [20]. There are multiple tools used for this purpose and the most common ones are flowcharts with Business Processes Modelling Notation (BPMN) [34].

Understanding the current processes is a fundamental step to design how the future processes should be with the support of PCS.

Gap analysis are the recommended ways to compare the operational performance to the target goals and identify the gap that needs to be bridged [20]. Based on this, different scenarios can be generated to demonstrate how a PCS can be used to support the current situation to different extent in order to reach the targeted performance.

4.4. Scenario evaluation

The last step of the framework is concerned with different scenarios evaluation based on cost-benefit analysis and risk management.

4.4.1. Cost-benefit analysis

Cost-benefit analysis is carried out to compare the expected costs for the different scenarios to the expected benefits. Cost-benefit analysis and are a financial method to compare different results from variety of actions [35]. The financial benefits for IT projects should be clear from the beginning and cost evaluation is one of the most important purposes of the business cases. Return On Investment (ROI) is commonly used as cost-benefit ratio, which is a performance measure used to evaluate the efficiency of a number of different investment[36]. The ROI is calculated as demonstrated in the formula below [36].

$$ROI = \frac{\text{Gain from investment} - \text{Cost of investment}}{\text{Cost of investment}} \qquad (1)$$

Finally, in order to take the uncertainty or changes in different parameters into the account to increase the accuracy of the cost analysis, sensitivity analysis is conducted. Sensitivity analysis are concerned with representing how the certainty, which can be apportioned to different sources of uncertainty in its output [37]. Sensitivity analysis has been grouped into four main categories: decision making or development of recommendations for decision makers, communication, increased understanding or quantification of the system, and model development [38].

4.4.2. Risk management

Software project risk management (RM) aims at improving the chances of achieving a successful project outcome and/or avoid project failure by identifying, analysing and handling risk factors [39]. Mathematically, R = P*I where R is the risk exposure attributable to a particular risk factor, P is the probability the undesirable event will be realized and I is the impact or magnitude of the loss if the event occurs [39]. Four inter-related approaches to risk management are: checklists [39,40], analytical frameworks [41], process models [39] and risk response strategies [42].

5. MULTIPLE CASE STUDIES

The framework was tested in two engineering companies specialized in production of heterogeneous catalysts and in the design of process plants and construction industry. In the former company the presented framework was tested on two projects and in the latter company on one project. The findings from the case studies, where the suggested approach was used, are elaborated in this chapter in terms of benefits, challenges and learning points.

5.1. Goal setting and benefit analysis

The overall projects goals should reflect the benefits to be achieved from implementing the system. The main benefits identified in this step are concerned with reduction in time needed to be allocated for meetings with experts and clear task assignment before further decisions are taken. The determined goals differ for the companies as they reflect the operational challenges the companies are currently facing and the stakeholder involved in the process of determining the goals.

Table 2. *Phase 1: Results from the case study: Goal setting and benefit analysis*

The main result	
Case 1	Empower the sales offices around the world, generate proposal faster to increase the hit rate and thereby increasing the sale.
Case2	Save time and resource, and become more accurate in order to increase competitiveness.
Case 3	Save resources, reduce the complexity causing redesign loops in the current process and to make experts' knowledge more available to all employees.

5.2. Stakeholder analysis

The tools proposed in this phase are use-case diagrams and MoSCoW for the requirement prioritization.

From system's functionality perspective, the time and resources needed for the development including integrations are specified. In addition use case diagrams were used for communication with domain experts. The benefits from using the methods in stakeholders' analysis after applying framework are listed as: full understanding of stakeholders' requirements, improved communication and task delegation in the team, which results in reduction in the number of resources and time consumption. The main obstacles in this step are related to unfamiliarity with the introduced tools resulting problems in changing the working routines. The main results from the cases in this phase are listed in Table 3.

Table 3. *Phase 2: Results from the case study: Stakeholder analysis*

The main result	
Case 1	The main stakeholders included: general managers and the engineers from both the sales and in the process design departments including all involved cost estimators, process engineers, and mechanical engineers. The main requirements included user interface allowing interactions with other software used internally at the company in order to make the system functional. The requirements prioritized according to MoSCoW.
Case2	The main stakeholders included: the general manager of the engineering department plus a couple of senior engineers that are the cost estimators in the sales department. The requirements prioritized according to MoSCoW.

| Case 3 | The main stakeholders included: project leader of the design, project leader of production, architects, engineers, cost calculation manager and IT experts. The main requirements were described in user-friendly interface with visualization, optimization of the design and accurate calculations. The requirements prioritized according to MoSCoW. |

5.3. Process analysis, scenario making and gap analysis

The tools proposed in this step are process mapping and GAP analysis. A common understanding of the current processes proved to provide learning points for all stakeholders. Especially in case 1, where the number of departments are involved, the team gained a deep understanding regarding the current process and what is the best way of connecting all the systems used in the process to anticipate all the integrations required for the future process.

The GAP analysis provided a good overview of the current performance at the companies as well as the desired future state. For using the new methods, trainings sessions were prepared, which was reported as a time consuming process. Afterwards, learning points were gained from analysing the current process and based on that the future scenarios where PCSs is used to support the processes to different extent. In all cases, numbers of redesigns loops were noticed due to lack and insufficient flow of information in the various steps of the processes. The project teams in all the cases found the GAP analysis a beneficial tool, which provided to be helpful to demonstrate how the different scenarios contributed to the overall goals. In addition it helped to communicate the need for implementing the PCSs in all cases and thereby increased the stakeholders' commitment to the project. The main results from the cases in this phase are listed in Table 4.

Table 4. *Phase 3: Results from the case study: Process analysis, scenario making and gap analysis*

The main result	
Case 1	The current situation is complex with lots of waiting times and meetings across department. Based on the current process, two scenarios were generated. In scenario 1, the system is used as an improved user interface, where the main aim is to empower the sales offices around the world. In scenario 2, the system includes all required integration to generate accurate proposals and process drawing templates in more efficient manners.
Case2	Based on the current situation in the engineering department, the team proposed a scenario for automating the sales and production process. The current situation includes too much iteration and waiting time for generating the specifications.
Case 3	The main challenge in the current process is complexity and need for experts' information resulting in great number of redesign loops. In scenario 1, the system is used only to support the engineering design process but in scenario 2, it is also used to support the generation of specifications for the production planning. Finally, GAP analyses are used to demonstrate how these scenarios contributed to the targeted goals.

5.4. Scenario evaluation

5.4.1 Cost-benefit analysis

This step demonstrates the financial benefits of PCSs project in short term and long term, which all stakeholders showed interest in. For case 1, the expected time savings due to automation of the process will not cover the cost of the saved man-hours as the quantity of the sold plant every year is too low. Therefore, the savings calculated based on selling one more plant per year. If the implementation of the PCS will lead to increased sale due to faster response time, that will lead to significant economic benefits. However, in case 2 and 3, the savings in terms of man-hours will provide the companies with savings due to higher quantity sold per year. The cost is calculated as the project cost, which includes the development and implementation and the yearly running cost which, includes licenses and maintenance activities. The main result from the cases in this phase are listed in Table 5.

Table 5. *Phase 4.1: Results from the case study: Cost-benefit analysis*

The main results	
Case 1	The approximate expected development cost (EUR) Scenario 1: 399,785 Scenario 2: 470,335 The expected benefits based on increased sale minus the maintenance work (EUR): Scenario 1: 1,007,862 Scenario 2: 1,068,468 ROI in the first year for scenario 1 = 152,10% ROI in the first year for scenario 2 = 127,17%
Case 2	The approximate expected project cost (EUR) Scenario 1: 99,600 The expected yearly savings, calculated as savings in man-hours minus maintenance work Scenario 1: 99,774 ROI in the first year for scenario 1 = 0,17%
Case 3	The expected project cost (EUR) Scenario 1: 154,666 Scenario 2: 200,160 The expected yearly savings, calculated as savings in man-hours minus maintenance work (EUR): Scenario 1: 407,997 Scenario 2: 487,128 ROI in the first year for scenario 1 = 163.7% ROI in the first year for scenario 2 = 143.36%

5.4.2 Sensitivity analysis

Sensitivity analysis are used to see if one of the parameters used to calculate the savings will change, and what will be the effects on the overall expected savings from the implementation the PCS. If there are great numbers of factors that have uncertainty, the sensitivity analysis can give the management sense of whether the project will still be profitable.

In case 3, the sensitivity analysis proofed to be a critical aspect for the management as it increased the credibility of the anticipated savings from implementing the system. Furthermore, even though only small parts of the anticipated savings will be gained, the implementation of the PCS will still be beneficial for the company. For case 2, the sensitivity analysis was not done as the project was the proof-of-concept for the PCS area at the company. In Table 6, the yearly benefits from

implementing the systems are listed in terms of lower bound, most likely and upper bound for cases 1 and 3.

Table 6. *Phase 4.2: Results from the case study: Sensitivity analysis*

The main result	
Case 1	Scenario 1: Lower bound: 200,256 EUR Most likely: 1,007,862 EUR Upper bound: 1,350,000EUR Scenario 2: Lower bound: 268,562 EUR Most likely: 1,068,468 EUR Upper bound: 1,453,556 EUR
Case 3	Scenario 1: Lower bound: 209,091 EUR Most likely: 407,997 EUR Upper bound: 523,760 EUR Scenario 2: Lower bound: 244,631 EUR Most likely: 487,128 EUR Upper bound: 628,004 EUR

5.4.3 Risk management

In case 1, there is risk of avoidance of the system and the good management regarding changing the mind-set of employees is needed. The solution was to involve all the users from the beginning to create the feeling of the ownership and commitment. In case 2, the risk which is threating the success of the project more than anything else is related to benefit realization of the project and trust in accuracy and stability of calculations. The solution was to implement a system which was proving all the data and formulas in the system. In case 3, the major threat was regarding whether the data could be incorporated in the system and also the acceptance of the system. In Table 7, the results from the risk management are listed.

Table 7. *Phase 4.3: Results from the case study: Risk management*

The main result	
Case 1	Scenario 1: Checklists have been prepared based on the experiences. The risk response strategies regarding avoidance and acceptance have been evaluated. Scenario 2: The same risk factors but in lower scale as the delivered system is more accurate, reliable, and fully automated as it is integrated with all the other systems. The extra risk will be regarding the IT process that could be challenging and time consuming and the need for resources (experts from business) to test the system.
Case2	Scenario 1: Internal resistance for using the system and lack of resources could be the biggest risk for the project.
Case 3	Scenario 1: Retrieving the relevant knowledge and structure in PCS and anticipated internal resistance of using the system. Scenario 2: The same risk factors but to greater extent as more knowledge has to be incorporated to the system and greater number of stakeholders are involved.

For case 1, Based on gap analysis and expenses and savings due to the project implementation, the second scenario accepted. The evaluated risks made the project team to make an backup plan. In case 2, there was only one scenario generated and therefore a selection of scenario was not required for case 2. Finally, in case 3

and scenario 1 was chosen as it had higher ROI and the risk associated was less. Furthermore by implementing scenario 1, the project can be extended when the usability of the system has been proven and the benefits from expanding the system can be revaluated.

6. DISCUSSIONS AND CONCLUSION

The suggested framework for making business cases for PCSs is developed based on both the available literature for IT and PCSs projects and the experiences from implementing PCSs in multiple case studies. The multiple cases introduced in this research have some similarities and differences that make them represented for this type of industry. First of all, the projects involve with complex products and process with engineering focus and secondly, the stakeholders and users of the system will be the engineers internally from business section at the companies. All the projects aim for decreasing the complexity in the current processes and thereby achieving economical benefits.

For PCS projects, all vague points should be cleared out before staring the project. In some cases, there is the matter of evaluation and prioritization of the projects based on the expected benefits generating from business cases. The paper clarifies that having a standard framework and being knowledgeable about the risks and the benefits of the project has a remarkable effect on decision making regarding choosing the project as well as decisions in early phases of the project. The suggested framework aligned with the suggested tools should help the team to focus and give priority goals and to the specific stakeholders' requirements, analysis of the current processes and development of different scenarios, and evaluation of different scenarios based on cost-benefits and risk factors.

The results of testing the framework in the case studies and the observations shows the interest between configuration team and especially the managers to shed light on the unclear points in the projects before initiations as well as estimate the cost and risks for PCS projects. Nevertheless, there are some limitations on the case studies due to the type of the industries and the projects were limited to ETO companies. Therefore, further studies of what the targeted ROI for PCS projects should be expected in different type of industries and for different applications would be beneficial. Furthermore, additional research is required regarding the cost estimation specifically for PCSs projects before doing any investment on them. There are not elaborated literatures on risk management for PCSs; however, there are number of threats for this kind of projects both in the development and especially in the implementation phase. Cost evaluation and the lists of costs have to be considered and the methods to estimate them are one of the fields that needs more research in the future. Finally, further testing is required in other types of industries. The reported challenges clarify some of the weak point of the suggested tools which need more research and simplicity.

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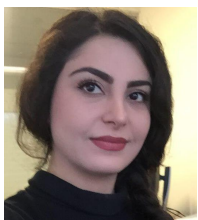
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