

Comparing the Gained Benefits from Product Configuration Systems Based on Maintenance Efforts

Sara Shafiee¹, Lars Hvam and Anders Haug

Abstract. Product Configuration Systems (PCSs) are automatic solutions to support and facilitate sales and engineering processes. PCSs are among the most successful applications of expert system technology and one of the drivers in the digitalization era. Therefore, there are several studies on the benefits of PCS. Such studies are, however, often relatively undetailed or unspecific about the costs and benefits of such projects. To address this issue, this paper presents studies of four PCS projects, which quantify benefits in terms of reduced working hours, and the costs in terms of development, implementation, and maintenance costs. The studies of the PCS projects each concern a 3-year utilization period. Our results show that the gained benefits from PCS has a growing trend over the years in case of proper maintenance. We also demonstrate the opposite is the case if not properly maintaining the PCSs. Furthermore, the study reveals that PCSs with the constant maintenance grow increasingly popular (i.e., use frequency) over time, while PCSs with poor maintenance decrease in popularity.

1 INTRODUCTION

Customers have become accustomed to having products customized to their personal needs while retaining the price associated with mass production [1]. Here, Product Configuration Systems (PCSs) can facilitate sales and production processes for customized products at prices comparable to mass produced [2]. PCSs affect the company's ability to increase the accuracy of the cost calculations in the sales phase, consequently increasing the efficiency of sales and engineering process [3]. PCSs are developed through describing information about product features, product structure, production processes, costs and prices in their knowledge bases [3]. PCSs support decision-making processes in the product engineering and sales phases by determining important decisions regarding product features and offering users information about product designs and costs [4], [5].

PCSs can bring substantial benefits to companies such as, shorter lead time for generating quotations, fewer errors, increased ability to meet customers' requirements regarding product functionality, use of fewer resources, optimized product designs, less routine work and improved on-time delivery [3], [6]–[8]. Although advantages of PCSs are evident, there are still some difficulties associated with required high investment [3], [9] and the high chances of failure [10]. Hence, researchers have provided empirical data from case studies to better understand the advantages, challenges, failure causes, expectations and risks

associated with PCS projects [5], [10]. Such studies are, however, often relatively undetailed or unspecific about the costs and benefits of such projects. Thus, although the literature provides a variety of methods to support the development and implementation of product configurators, it remains unclear how to estimate the costs and benefits for different scenarios [9]–[11].

To harvest the benefits of a PCS, great efforts and investments must be undertaken [5]. In this context, some research point to a lack of PCS maintenance as the main reason for project failure [10], [12]. The maintenance process in PCS involves constantly updating the PCS knowledge base and being responsive to including alternative requirements [12].

The research presented in this paper uses a case company to investigate the financial consequences of not maintaining a PCS properly by comparing four of its projects. The aim is to evaluate the trend of the gained benefits from PCS during the years after development. Here, it is the assumption that PCS projects benefits from proper and constant maintenance and updating in the years after implementation [12]. This study also sets out to generalize based on these findings concerning how the profitability of the PCS projects in the years after development can be forecasted. With the aim to investigate these effects, the following propositions are developed:

Proposition 1. A PCS project will increase popularity and produce greater benefits in the years after development in case of continuous maintenance and updating.

Proposition 2. A PCS project will lose popularity and benefits in the years after development in case of not employing continuous maintenance and updating.

To achieve this, we calculate the costs and benefits of four different projects during their last 3-years. In this context, we focus on the saved man-hours in the calculation of benefits in the four PCS projects. Then, we compare the yearly benefits from each project to illustrate any trend of change during the 3-years. Finally, based on the knowledge in the literature and our research propositions, we demonstrate the results using graphs and discuss the findings.

2 RELATED WORKS

The relevant literature was reviewed to clarify the present study's position in relation to existing research. This allowed us not only to ascertain whether this research has the potential to add to the existing knowledge but also to identify which parts of the available knowledge are relevant to define the study's scope. In this section, the relevant literature on calculating the PCS cost- benefits and PCS complexity is reviewed and subsequently utilized for

¹ Mechanical Engineering Department, Technical University of Denmark, Denmark, email: sashaf@dtu.dk

calculating the ROI (return on investment) and PCS complexity in four cases of this study. The importance of constant maintenance of PCS projects and its influence on PCS projects' profitability is also investigated. Finally, PCS complexity and complexity measurements are discussed.

2.1 Cost benefit analysis for PCS

Several studies have addressed the cost factors of PCSs. Forza and Salvador [7] mentioned that a large investment in terms of man-hours may be needed to implement a PCS. Hvam [13] reported that in one case, the cost of developing and implementing a PCS in a large ETO companies was approximately USD 1 million, with operating costs of USD 100,000 per year. These costs are compared to the usage of the system, which is estimated in order to generate a budget and detailed quotations, according to which the total sales price is USD 200 million [11]. Haug et al. [14] elaborate on how man-hours in the configuration process can be reduced by up to 78.4%. Moreover, Hvam et al.'s [15] study indicates that after utilization of PCS at the case company, the lead time required to generate an offer was reduced by 94–99%. The reduction can be traced to automation of routine tasks and elimination of the iterative loops between domain experts, as PCS makes all product knowledge available [16]. Three main types of benefits are mentioned in the literature [9]: (1) time reduction (man-hours and lead time), (2) product specification quality improvement and (3) sales increase.

Costs of configurators has also been discussed [7], [13] and they include software licenses (the cost of buying the software and annual licenses) as well as internal and external man-hours for modelling, programming, and implementing the configurator. The costs consist partly of the initial costs of making the configurator and partly of the annual costs of maintaining and operating it [17]. However, there are still some hidden costs, such as the time needed for people to learn and use the system – costs that, however, can be measured as man-hours [18].

2.2 Documentation and maintenance of PCSs

One of the main challenges when using PCSs concerns a lack of documentation, which can lead to incomplete and outdated systems that are difficult to understand [19], [20]. For a company using a PCS, it is therefore crucial to have an efficient system for documenting the structure, attributes, and constraints modelled within the system, as well as to facilitate communication between PCS developers and domain experts [12]. Documentation is a vital part of all IT projects, as it is used for sharing knowledge between people and reducing knowledge loss, when team members become inaccessible [10], [21], [22]. The documentation of PCS includes modelling, maintaining and updating the product model, and storing all information related to the products' attributes, constraints and rules in the PCS [4].

Studies of companies using configurators have revealed that, without a planned systematic approach, companies are unable to develop and maintain their configurators [20]. Modelling techniques are used as documentation tools alongside the task of communication and validation of product information [16], [23]. Research supports the modelling process by adding software support and integrating these different modelling techniques (PVM (product variant master) and CRC (class-responsibility-

collaboration) cards) [8], [24]. Other studies report that one the main reason for the PCS projects failure is the lack of the proper documentation and maintenance [10]. In other words, not performing maintenance and updating tasks can have significant negative consequences [25], [4], [26], [27].

The economic implications of the maintenance of data repositories can be examined in terms of costs and benefits [28]. The results of such analyses indicate that although the cost of maintaining a PCS can be relatively high, it cannot be ignored as it risks wasting the investment. Hence, economic and business benefits can justify the maintenance costs, as continuous updates of the PCS are needed to ensure the accuracy and timeliness of the configuration data.

2.3 Complexity analysis for PCS

Complexity is one the most discussed challenges in software development and maintenance [16], [29]. In PCS projects, the complexity of PCS is associated directly with the complexity of targeted products. As PCS complexity increases, the task of maintaining the PCS becomes more challenging and costly [30].

To measure the complexity of PCSs, Brown et al. [31] defines three major complexity dimensions; 1) execution complexity, 2) parameter complexity, and 3) memory complexity. Execution complexity covers the complexity involved in performing the configuration actions that make up the configuration procedure, while the memory complexity refers to the number of parameters that system manager must remember. In this paper, we measure the complexity involved in the knowledge that domain expert provides during the creation of the configuration model [31], which could also be an indicator of the product complexity leading to the PCS complexity. Therefore, we assess the parameter complexity in terms of two major PCS knowledge base characteristics: attributes and constraints (Table 1).

Table 1. Complexity assessment in terms of parameters in PCS [12]

	No. attributes	No. constraints
Low complexity	500 - 1300	200-800
Medium complexity	1300-2000	800-1200
High complexity	>2000	>1200

In this paper, we measure the complexity of each PCS projects as sum of attributes and constraints. The complexity is highlighted as one of the main the background information on PCS projects as the higher complexity dictates the higher effort in development and maintenance tasks for PCS projects.

3 RESEARCH METHODOLOGY

Different research has employed cost-benefit analysis for PCSs using different cost factors such as the saved man-hours, increased sales, improved quality and reduction in errors and defects. To date, there is little research that investigates the trends of cost-benefits in PCS projects over time to estimate the changes in profitability considering different variants. The number of research papers providing detailed data from real case projects are also limited. Thus, a explorative approach was employed in the form of a case study approach.

The company selected for case studies produces highly engineered products and technology. More specifically, studies of

four configurator projects were carried out at a large Danish ETO company, which produces chemical processing systems. The case company was chosen because it:

- offers highly engineered and complex products;
- had recently implemented PCS projects – including projects with frequent and more sporadic maintenance efforts;
- had measured/estimated costs and benefits of PCS projects over the last three years; and
- offered a unique level of access to project data.

The reason for choosing one case company for the four studies of PCS projects was to provide the in-depth data analysis and be able to observe the changes in benefits over time, while keeping many external factors (such as organizational culture, IT department and PCS software shell) as fixed as possible.

ETO companies normally engineer the products with high complexity based on customer request. Hence, we chose the case projects with the most complex products. The initial criteria for choosing the four projects were:

- maximum similarities between the four PCS project contexts to keep external factors constant;
- differences in costs and benefits;
- similar users (engineers);
- different PCS use frequency (number of generated quotes);
- two projects with continuous maintenance and two with limited maintenance during the last three years;
- same IT team and the involvement of similar tasks during development and maintenance;
- similar software platform and integrations.

All the PCS projects focused on sales process automation in situations where generated quotations were not significantly affected by market fluctuations, depended on the requests from the customer. Here, the company experts generate the quotes from the sale PCS in order to offer the price and all the specifications to the customer based on his/her requirements. Cases 1 and 2 received continues proper maintenance during the last three year; while cases 3 and 4 has been rarely updated. Table 2 shows information related to the four selected PCS projects. The complexity ratio on different projects indicates the task of maintaining the PCS as the higher complex projects require more challenging and costly maintenance tasks.

Table 2. Background information on case studies

Case Studies	Complexity of the configurator (sum of attributes and constraints)
Case 1	High = 3400
Case 2	Medium = 2100
Case 3	Medium = 1850
Case 4	Low = 790

In this paper, we focus only on saved man-hours as our benefits measure when comparing the four projects. The reason for

choosing man-hours is the ease of access to these data, as well as the uncertainty related to other factors – as, for example, increased sales and improved product quality, which could be results of other factors than the PCS. The number of saved man-hours before and after using the configurator and the gained benefits based on the saved man-hours are calculated for the last 3-years. The total costs of each project is calculated based on the development, implementation and the yearly running costs (such as licenses and maintenance activities) for the last 3-years.

Analyzing the costs and benefits from the last 3 years at the case company allows us to benefit from the use comparative multiple case study method [32], [33]. Case-based research seeks to find logical connections among observed events, relying on knowledge of how systems, organizations, and individuals work [33], [34]. Furthermore, case studies provide researchers with a deeper understanding of the relations among the variables and phenomena that are not fully examined or understood [35], for instance, the impact of the proper maintenance of the PCS projects on the gained and constant benefits increase during the years.

4 CASE STUDIES

Table 3 illustrates all the figures related to the gained benefits based on saved man-hours for each project during the first year including development. All the costs are in Danish Kroner.

Table 3. Calculation of the total benefits in DKK based on the saved man-hours in the first year of development

Case Studies	Number of quotes per year through configurator	Benefit per quote in hours (saved man-hours)	Total benefit per year (just based on saved man-hours)	Total Costs (development + maintenance + licenses)
Case 1	240	10,3	987.840	527.000
Case 2	295	1	118.000	157.000
Case 3	200	2	160.000	565.000
Case 4	270	0,5	54.000	437.000

The calculation of the total benefits in Table 4 illustrates all the figures related to the gained benefits based on saved man-hours for each project during the second year. For the second year, we only calculated the maintenance costs and license costs (only for users), as there was not any development, but only maintenance.

Table 4. DKK based on the saved man-hours in the second year after development

Case Studies	Number of quotes per year through configurator	Benefit per quote in hours (saved man-hours)	Total benefit per year (just based on saved man-hours)	Total Costs (maintenance + licenses)
Case 1	380	10,3	1.560.000	136.000
Case 2	310	1	124.000	70.000
Case 3	80	2	64.000	40.000
Case 4	150	0,5	30.000	70.000

Table 5 illustrates all the figures related to the gained benefits based on saved man-hours for each project during the third year. Again, for the third year, we only calculated the maintenance costs

and licenses costs (only for users), as there was not any development, but only maintenance for case 1 and 2, while not for case 3 and 4.

The numbers in Table 3-5 show a positive trend towards higher number of generated quotations and higher benefits for the case PCS projects with continues maintenance effort. It also demonstrates the negative trend in both cost and benefits for the PCS project with no maintenance efforts. The results demonstrate that the rate of using the PCSs increases over time if the system is maintained and updated.

Table 5. Calculation of the total benefits in DKK based on the saved man-hours in the third year after development

Case Studies	Number of quotes per year through configurator	Benefit per quote in hours (saved man-hours)	Total benefit per year (just based on saved man-hours)	Total Costs (maintenance + licenses)
Case 1	422	10,3	1.736.000	115.000
Case 2	320	1	128.000	52.000
Case 3	20	2	16.000	22.000
Case 4	60	0,5	12.000	22.000

5 DISCUSSION

The case studies demonstrate a positive trend in popularity and use of the PCS with continuous updates, which leads to the increase in PCS profitability.

Analyzing the cost benefits across three years for case 1 and 2 clarifies that if the PCS is maintained and updated continuously, they will be used more over the time and turn to become an important tool among the experts. In other words, experts would give up using other tools (such as excel sheets) and all use the configuration system. As the number of the quotations generated increase, the more man-hours will be saved due to the automation and the benefits of using the PCS increase. Figure 1 demonstrates the yearly benefits for each of the case studies. Apart from the complexity or size of the PCS and number of saved hours, case 1 and 2 presented PCS projects with the tendency to increases in benefits during the years. However, as illustrated in Figure 1 cases 3 and 4 have a huge decrease in use and benefits during the last three years due to the lack of maintenance.

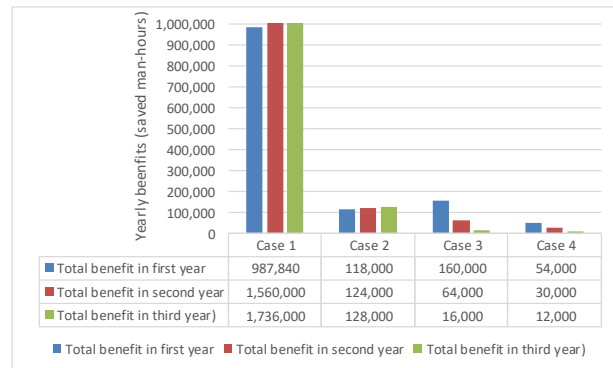


Figure 1 The total benefits based on the saved man-hours for each of the PCSs during the last three years

Moreover, as the benefits of the projects increase, there is a trend of decrease in the total costs of the projects per year. As illustrated in Figure 2, for cases 1 and 2, the cost in year 1 includes development cost based on the man-hours spent on development, while in years 2 and 3, there will be just minor updates and maintenance. For Cases 3 and 4, the maintenance efforts are just the costs paid for licenses, after which they decrease significantly.

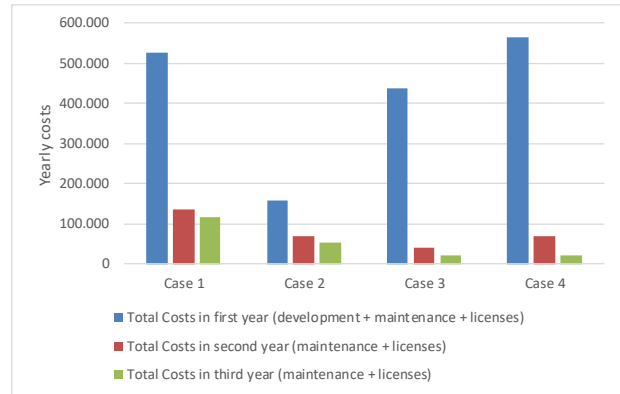


Figure 2 The total benefits based on the saved man-hours for each of the PCSs over three years

It can be understood from the numbers and graphs that the cost of maintenance are very low as compared to the investments for the initial development of a PCS. However, the maintenance efforts and costs can have a dramatic influence on the popularity and benefits of PCS projects.

6 CONCLUSION

The aim of this study was to understand the influence of the maintenance of the PCSs on gained benefits in terms of saved man-hours. Empirical data was gathered from an ETO company based on the previous 3-year results, which confirmed the propositions made. Specifically, numbers for the cost and benefits for the last 3 years was available from the case company, and the complexity was estimated based on the number of attributes and the number of constraints in PCS. The analysis of these data led to the conclusion that there is a positive correlation between continuous maintenance in PCS projects and the level of gained benefits in the selected case projects. If not engaging in maintenance efforts, in the case projects the money is wasted on licenses and other fixed costs for PCSs. As the studied projects showed, projects that receive no maintenance can result in financial loss – since users do not use PCS that are not up-to-date because of the lack of maintenance efforts.

This research is a first step in exploring the impact of maintenance on the saved man-hours in PCS project. However, there are generalization limitation for the paper due to the limited number of cases and data. For future research, the study of this paper identified a number of factors, which can influence PCS projects' costs and benefits, needing to be further studied. These factors include employee experiences, user expertise, level of details included in PCSs, and organizational culture.

In this study, we compared four projects using only one variable, namely 'saved man-hours'. Thus, there is a need for further research to analyze different factors, which may contribute

to the benefits of PCS projects. Future research needs to cover both the variety of companies except the ETOs as well as a wide range of case studies. For practice, the results of the paper may motivate companies to give maintenance efforts a higher priority, as opposed to solely focusing on the development and implementation tasks.

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