Cost Benefit Analysis in Product Configuration Systems

Sara Shafiee[1] and **Alexander Felfernig** and **Lars Hvam** and **Poorang Piroozfar** and **Cipriano Forza**

Abstract. Companies' reports indicate a mixture of success and failure in Product Configuration Systems (PCS) projects. Moreover, the attention paid to PCS across different industries is increasing. Therefore, more studies are needed to analyze risks, costs, and benefits of PCS. This paper uses real case projects to demonstrate the cost-benefit analysis of PCSs in real industrial setups. Hence, this article quantifies savings in terms of reduced working hours, and the cost implications with reference to development, implementation, and maintenance. The study fills the gap in previous research by addressing what the influence of other factors on gained cost-benefits from PCSs are likely to be. This study aims to explain why some PCS projects are more cost-effective than the others. While there are a number of factors affecting the cost-benefit analysis in PCS, the focus of this study remains mainly on the number of users and complexity of the project. The comparison in the case studies revealed that both factors have a positive direct correlation with the gained cost-benefits from PCSs.

1 INTRODUCTION

Product Configuration Systems (PCS) enable companies to develop product alternatives to facilitate sales and production processes [1]. This is achieved through incorporating information about product features, product structure, production processes, costs and prices [2]. PCSs support decision-making processes in the engineering and sales phases of a product, which can determine the most important decisions regarding product features and cost [3]. PCSs affect the company's ability to increase the accuracy of the cost calculations in the sales phase and consequently increases the products' profitability in sales and engineering process [2].

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 [2], [4]–[6]. Although advantages of PCSs are evident, there are still some difficulties associated with high cost [2], [7] and considerable chances of failure [8] in their implementation projects.

The aim of this paper is to evaluate the influence of different factors on the gained cost-benefits of PCS such as employees' experiences and organizational culture [9][10]. More specifically, the objective of the paper is to evaluate the influence of the two factors on the cost-benefits gained from different PCS projects: (1) number of users and (2) complexity. This study also sets out to find out why some PCSs are more beneficial than the other PCS projects and how the profitability of the PCS projects in the future can be forecasted. Aiming to investigate these effects, the following propositions were developed:

Proposition 1. The higher the number of users in PCSs, the higher Return on Investment (ROI) and cost-benefits**.**

Proposition 2. The higher the complexity in PCSs, the higher ROI and cost-benefits**.**

Firstly, we calculate the cost of three different projects during their last four years. Secondly, we calculate the cost-benefits during the last four years. In this research, we focus on the saved man-hours in calculating the ROI on multiple case projects in one case company, while investigating different factors influencing the ROI. Then, the data related to the number of users in the last year and the complexity of PCSs is retrieved. Finally, based on the knowledge in the literature and our research propositions, we demonstrate the results using graphs and discuss the findings.

2 LITERATURE STUDY

In this section, the relevant literatures for calculating the PCS cost-benefits and PCS complexity are reviewed which will then be utilized for calculating the ROI and PCS complexity in the cases of this study.

2.1 Cost benefit analysis for PCS

The results from the literature review shows that by utilizing PCS reduced man-hours and lead-time for generating the specifications is acknowledged in numerous previous research [5], [11]–[28]. Forza et al. [17] demonstrate a reduction in man-hour from 5-6 days to only 1 day through using PCS. Haug et al. [18] elaborate on how man-hours in the configuration process can be reduced by up to 78.4%. Moreover, Hvam et al.'s [25] 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 [29].

Several researches have quantified the benefits of PCS in terms of reduced man-hours, lead-time and improved the quality of product specifications. However, none of the researchers have investigated the factors which are influencing the cost-benefit analysis and why some of the PCS projects are more cost effective than the others. In this research, we focus on the saved man-hours which is a simple and quantified indicator to calculate the ROI to fill a knowledge gap in the literature.

Discussions concerning the unpredicted costs of PCS projects indicate that the rough estimates involved in cost analysis are considered a challenge that needs more attention from academia [30]. The financial benefits of PCS projects should be clear from

---

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

the beginning, and cost evaluation is important from the initiation phase. Cost-benefit analysis is used to compare the expected costs and benefits for different scenarios and the results from a variety of actions [31]. ROI, which is commonly used as a cost-benefit ratio, is a performance measure used to evaluate the efficiency of a number of different investments [32], and has been used to determine the profitability of PCS projects [10].

2.2 Complexity analysis for PCS

To measure the complexity of PCS, Brown et al. [33] categorize them into three major components; 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, the parameter complexity is the most important category, as it measures the complexity involved in the knowledge that domain expert provides during the creation of the configuration model [33]. Therefore, we assess the parameter complexity in terms of two major parameters inside the PCS: attributes and constraints (Table 1).

Table 1. Complexity assessment in terms of parameters in PCS [34]

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

3 RESEARCH METHOD

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 this study's scope.

Cost-benefit analysis has been performed in different research areas by calculating the saved man-hours, increased sales, improved quality and reduction in errors and defects. To date, there is no research to investigate the factors influencing cost-benefits in PCSs and to answer why some of the PCS projects are significantly more cost effective.

In the current research, the benefit per quote (in man-hours) and the total cost of the projects is provided by the company. The amount of saved man-hours before and after using the configurator and the gained benefits based on the saved man-hours are calculated. In this study, the total cost of each project is calculated as the project cost, which includes the development, implementation and the yearly running cost (such as licenses and maintenance activities) for the last year.

In this research, we use multiple case studies to evaluate two propositions in one ETO (Engineer To Order) company. The company is a chemical company producing catalysts and process plants and the selected three projects are three catalysts types. The reason for choosing one case company is to provide the in-depth data analysis and observed a trend between the selected factors while all the other factors including organizational culture are fixed. The criteria for choosing the three project (three catalyst products) is the maximum similarities between these three PCS projects to be able to keep other factors constant; the required

differences for the selected factors (number of users and complexity); the similar users (engineers); Almost the same rate for the using configurators (number of generated quotes); the same IT team and the involvement of similar tasks during development and maintenance; similar setup of the knowledge; similar software and integrations.

The analysis has been performed during the last 4 years at the case company which allows us to benefit from the strength of using multiple case study method [35], [36]. Furthermore, case studies provide researchers with a deeper understanding of the relations among the variables and phenomena that are not fully examined or understood thus far [37], for instance, the factors with an impact on the cost-benefits from PCS projects. There are multiple data sources such as archived documents and triangulated observations.

4 CASE STUDIES

The company selected as the case study produces highly engineered products and technology. The market environment is highly competitive, and thus delivery time and costs are critical. The main motivation for implementing the PCS was to reduce the time required to respond to customer inquiries in order to increase the company's overall competitiveness. Hence, in this study the focus is on lead-time reduction that leads to reduction in resources at the company and directly affects the cost implications.

Three selected projects from three different departments with different number of users and complexities were selected. All three projects are comparable as (1) they all are selected from one case company, (2) they are highly engineered-to-order and complex products, (3) they have been in use during the last 4 years to support sales processes, (4) they have totally different cost-benefits results, and (5) they have are different in terms of complexity and numbers of users. Table 2 demonstrates the data related to three selected sales (commercial) PCS projects. The number of users refers to the sum of the personnel at the company who are using the system (e.g. in Case 1, 50 users constantly use the system). The complexity in this research is relatively studied and different complexities in different projects is compared.

Table 2. Number of users and complexity per project

Case Studies	Number of users per PCS	Complexity of the configurator (sum of attributes and constraints)
Case 1	50	Medium/High = 3400
Case 2	13	Medium = 2100
Case 3	10	Low = 600

Table 3 illustrates all the figures related to the gained benefits based on saved man-hours for each project during the last year.

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

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) per year	ROI
Case 1	240	10,3	987.840	527.000	90%
Case 2	295	1	118.000	157.000	25%
Case 3	270	0,6	65.000	110.000	-40%

5 DISCUSSIONS

The case study results demonstrate how the number of the users and complexity of the configurators' projects have an impact on saved man-hours and cost-benefits in PCS projects.

Analyzing the correlation of the number of users to cost-benefits, clarify the fact that if the department is larger and the potential number of users are higher for one specific PCS, then the expected benefit regarding saved man-hours from that configurator is higher (Figure 1). The number of quotations generated for each of the cases the year before are almost the same (Table 3) but Case 1 saves more man-hours which could be because the time and number of the users for quotation process is higher compared to the other cases.
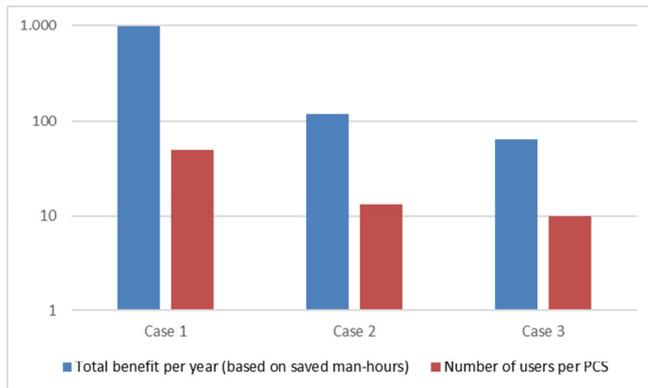

Figure 1. The total cost benefits related to the number of users per PCS per year

Analyzing the complexity related to the cost-benefit calculation illustrates a trend in the benefits gained from PCS and their relative complexity ratio. Figure 2 demonstrates a trend between the complexity of the PCS project and cost-benefits implications.

The complexity is calculated based on the attributes and constraints in each project and shows the size of the product as well. The results demonstrate that if the company develops a PCS for more complex product, the project cost will be higher (Table 3), and the benefits will be higher conclusively.
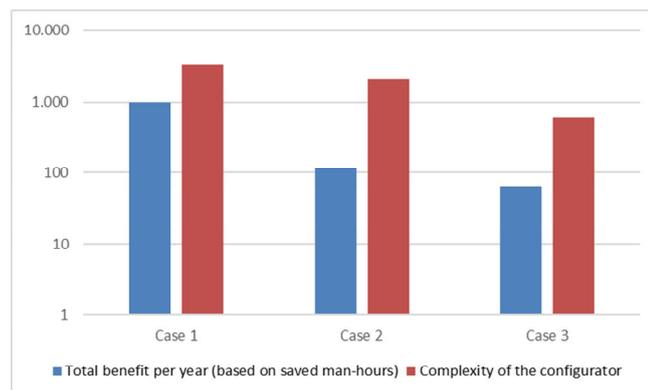

Figure 2. The total cost benefits related to the PCS complexity PCS per year

Figure 3 demonstrates the total cost-benefits, number of users and complexity of each case project in one year. As discussed before, there is a direct positive correlation between cost-benefit analysis and both the number of users and the complexity of the project.
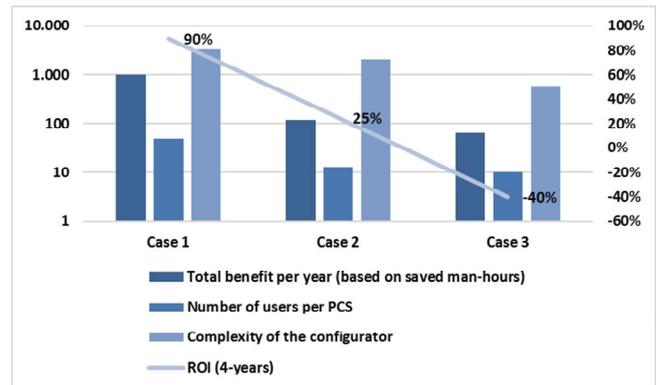

Figure 3. The total cost benefits, number of users, complexity per PCS per year

6 CONCLUSION

The aim of this study was to measure the influence of the number of users and the complexity of the PCS project on gained benefits based on the same man-hours. The empirical data is gathered from an ETO company based on the previous 4-year results and these results confirmed the propositions. In detail, the gained benefit, number of users, and the PCS complexity per year were measured. The number of users' data was available from the case company and the complexity was calculated based on the number of attributes and the number of constraints in PCS. The PCS complexity illustrate the relative complexity in the product. In order to be able to make the sales configurator for each of these products, a specific number of input, outputs, and finally attributes, constraints, and rules are required in PCS.

The analysis led to the conclusion that there is a positive correlation between the number of users in one PCS and the level of direct savings. The higher number of the employees indicates that PCS can save more man-hours in that specific department. The more complex the PCS project, the more time is needed for developing the project which has been calculated as ROI. However, it seems complex projects save more man-hours. Complex PCS seem to compensate the development efforts and maintenance hours since in such cases, more stakeholders' time is saved to deliver more complicated quotations.

This research is in the first step in exploring the impact of other factors on the saved man-hours in PCS project. There are lists of factors which can influence the PCS projects cost-benefit analysis which can be explored in the future. These factors may be listed as employees' experiences and users' expertise, level of details included in the configurator, and organizational culture. This study considers two specific factors as outstanding ones based on the experience and verified two propositions. In this study, we provided one case company and three projects with in-depth data and we observed a trend between the selected factors. Therefore, it requires further research and additional cases to analyze different factors which may influence the gained benefits from PCS projects. Further research is required to cover both the variety of companies except the ETOs as well as a wide range of case studies.

REFERENCES

[1] A. Felfernig, S. Reiterer, F. Reinfrank, G. Ninaus, and M. Jeran,

"Conflict Detection and Diagnosis in Configuration," in *Knowledge-Based Configuration: From Research to Business Cases*, A. Felfernig, L. Hotz, C. Bagley, and J. Tiihonen, Eds. Morgan Kaufman, 2014, pp. 73–87.

[2] C. Forza and F. Salvador, *Product information management for mass customization: connecting customer, front-office and back-office for fast and efficient customization*. New York: Palgrave Macmillan, 2007.

[3] L. Hvam, N. H. Mortensen, and J. Riis, *Product customization*. Berlin Heidelberg: Springer, 2008.

[4] A. Felfernig, L. Hotz, C. Bagley, and J. Tiihonen, *Knowledge-Based Configuration From Research to Business Cases*. Newnes: Morgan Kaufman, 2014.

[5] C. Forza and F. Salvador, "Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems," *International Journal of Production Economics*, vol. 76, no. 1, pp. 87–98, Mar. 2002.

[6] S. Shafiee, "Conceptual Modelling for Product Configuration Systems," Technical University of Denmark, 2017.

[7] A. Haug, L. Hvam, and N. H. Mortensen, "Definition and evaluation of product configurator development strategies," *Computers in Industry*, vol. 63, no. 5, pp. 471–481, Jun. 2012.

[8] S. Shafiee, K. Kristjansdottir, and L. Hvam, "Business cases for product configuration systems," in *7th international conference on mass customization and personalization in Central Europe*, 2016.

[9] L. L. Zhang, "Product configuration: a review of the state-of-the-art and future research," *International Journal of Production Research*, vol. 52, no. 21, pp. 6381–6398, Aug. 2014.

[10] K. Kristjansdottir, S. Shafiee, L. Hvam, M. Bonev, and A. Myrodia, "Return on investment from the use of product configuration systems – A case study," *Computers in Industry*, vol. 100, no. July 2017, pp. 57–69, 2018.

[11] M. Ariano and A. Dagnino, "An intelligent order entry and dynamic bill of materials system for manufacturing customized furniture," *Computers & Electrical Engineering*, vol. 22, no. 1, pp. 45–60, Jan. 1996.

[12] M. Aldanondo, S. Rougé, and M. Véron, "Expert configurator for concurrent engineering: Cameleon software and model," *Journal of Intelligent Manufacturing*, vol. 11, no. 2, pp. 127–134, 2000.

[13] L. Ardissono *et al.*, "A Framework for the Development of Personalized, Distributed Web-Based Configuration Systems," *AI Magazine*, vol. 24, no. 3, p. 93, 2003.

[14] V. E. Barker, D. E. O'Connor, J. Bachant, and E. Soloway, "Expert systems for configuration at Digital: XCON and beyond," *Communications of the ACM*, vol. 32, no. 3, pp. 298–318, Mar. 1989.

[15] M. Gronalt, M. Posset, and T. Benna, "Standardized Configuration in the Domain of Hinterland Container Terminals," *Series on Business Informatics and Application Systems Innovative Processes and Products for Mass Customization*, vol. 3, pp. 105–120, 2007.

[16] C. Forza and F. Salvador, "Product configuration and inter-firm coordination: An innovative solution from a small manufacturing enterprise," *Computers in Industry*, vol. 49, no. 1, pp. 37–46, Sep. 2002.

[17] C. Forza, A. Trentin, and F. Salvador, "Supporting product configuration and form postponement by grouping components into kits: the case of MarelliMotori," *International journal of mass customisation*, vol. 1, no. 4, pp. 427–444, 2006.

[18] A. Haug, L. Hvam, and N. H. Mortensen, "The impact of product configurators on lead times in engineering-oriented companies," *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, vol. 25, no. 2, pp. 197–206, Apr. 2011.

[19] M. Heiskala, J. Tiihonen, and K. Paloheimo, "Mass customization of services: benefits and challenges of configurable services," in *Frontiers of e-Business Research (FeBR 2005)*, 2005, pp. 206–221.

[20] M. Heiskala, K. Paloheimo, and J. Tiihonen, "Mass customization with configurable products and configurators: a review of benefits and challenges," in *Mass customization information systems in business*, no. C, Finland: IGI Global, 2007, pp. 75–106.

[21] J. Heatley, R. Agarwal, and M. Tanniru, "An evaluation of an innovative information technology - the case of carrier expert," *Journal of Strategic Information Systems*, vol. 4, no. 3, pp. 255–277, 1995.

[22] L. Hvam, M. Malis, B. Hansen, and J. Riis, "Reengineering of the quotation process: application of knowledge based systems," *Business Process Management Journal*, vol. 10, no. 2, pp. 200–213, 2004.

[23] L. Hvam, "Mass customisation in the electronics industry : based on modular products and product configuration," *International Journal of Mass Customisation*, vol. 1, no. 4, pp. 410–426, 2006.

[24] L. Hvam, "Mass customisation of process plants," *International Journal of Mass Customisation*, vol. 1, no. 4, pp. 445–462, 2006.

[25] L. Hvam, A. Haug, N. H. Mortensen, and C. Thuesen, "Observed benefits from product configuration systems," *International Journal of Industrial Engineering: Theory, Applications and Practice*, vol. 20, no. 5–6. 2013.

[26] T. D. Petersen, "Product Configuration in ETO Companies," in *Mass customization information systems in business,* 2007, pp. 59–76.

[27] J. J. Sviokla, "An Examination of the Impact of Expert Systems on the Firm: The Case of XCON," *MIS Quarterly*, vol. 14, no. 2, p. 127, 1990.

[28] M. Yoshioka, M. Oosaki, and T. Tomiyama, "An Application of Quality Function Deployment to Functional Modeling in a Knowledge Intensive Design Environment," in *Knowledge Intensive CAD Vol 1*, no. January, Springer US, 1996, pp. 300–314.

[29] S. Shafiee, K. Kristjansdottir, L. Hvam, and C. Forza, "How to scope configuration projects and manage the knowledge they require," *Journal of Knowledge Management*, vol. 22, no. 5, pp. 982–1014, 2018.

[30] S. Shafiee, L. Hvam, and M. Bonev, "Scoping a product configuration project for engineer-to-order companies," *International Journal of Industrial Engineering and Management*, vol. 5, no. 4, pp. 207–220, 2014.

[31] A. C. Haddix, S. M. Teutsch, and P. S. Corso, *Prevention effectiveness: a guide to decision analysis and economic evaluation*. Oxford University Press, 2003.

[32] P. A. Lemoine, H. C. Woodard, and M. D. Richardson, "Return on Investment," in *Handbook of Improving Performance in the Workplace, Volume Two: Selecting and Implementing Performance Interventions*, 2010, pp. 302–308.

[33] A. B. Brown, A. Keller, and J. L. Hellerstein, "A Model of Configuration Complexity and its Application to a Change Management System Aaron," *IEEE Transactions on Network and Service Management*, vol. 4, no. 1, pp. 13–27, Jun. 2007.

[34] S. Shafiee, L. Hvam, A. Haug, M. Dam, and K. Kristjansdottir, "The documentation of product configuration systems: A framework and an IT solution," *Advanced Engineering Informatics*, vol. 32, pp. 163–175, 2017.

[35] A. H. Van de Ven, "Nothing is quite so practical as a good theory," *Academy of Management Review*, vol. 14, no. 4, pp. 486–489, 1989.

[36] D. M. McCutcheon and J. R. Meredith, "Conducting case study research in operations management," *Journal of Operations Management*, vol. 11, no. 3, pp. 239–256, Sep. 1993.

[37] J. Meredith, "Building operations management theory through case and field research," *Journal of Operations Management*, vol. 16, no. 4, pp. 441–454, 1998.