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COMPARING THE PRODUCT CONFIGURATION BENEFITS IN ENGINEERING AND QUOTATION PHASES

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Abstract: *Due to the increased popularity of Product Configuration Systems (PCS), researchers reported both the success and failure stories of PCS. However, most of the literature does not reveal the real cost and befits from PCS due to the lack of access to real case companies datum. Therefore, there is little detailed quantification of the benefits, costs, and return on investment (ROI) from using PCS published in the literature. There are little research to compare the ROI of PCS project both in quotation and engineering phase. Hence, this article aims at analyzing the short-term benefits and the cost from developing, implementing and maintaining product configuration systems (PCSs). The analyses presented in this study are based on need of the European leading engineering and design office for heat exchangers.*

Key Words: ***Product Configurator, cost-benefit analysis, Case Company, Return On Investment (ROI)***

1. INTRODUCTION

A product configurator is a type of expert system that supports product specification processes by providing the user with product choices while ensuring that only valid combinations can be chosen [1], [2]. Product Configuration Systems (PCS) enable companies to develop product alternatives to facilitate sales and production processes [3]. PCSs automate decision-making processes in the engineering and sales phases of a product, which can determine the most important decisions regarding product features and cost [4], [5]. 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 [6]–[8].

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 design, less routine work and improved on-time delivery [2], [6], [9], [10]. Although advantages of PCSs are evident, there are still some difficulties associated with high investments [6], [11], [12] and the chances of failure [11], [13].

The aim of this paper is to analyze the cost-benefits of PCS by calculating the costs including the software, development and maintenance costs [14][15]. Moreover, the benefits are also calculated only based on the saved man-hours during both quotation and implementation of the ordered product. Therefore, we only focus on the most reliable and quantifiable benefit category and ignore all the other benefit categories such as increase in sale or increase in the quality [15]. More specifically, the objective of the paper is to evaluate the cost-benefits gained from PCS projects in one engineering company during the first year of use of PCSs to calculate the ROI: (1) for the quotation process and (2) for the engineering or realization process. Aiming to investigate these effects, the following proposition was developed:

Proposition. The ROI and cost-benefits are higher in engineering phase compared to the quotation phase.

Firstly, we calculate the cost of one specific product and the investment costs on PCS for one year. Secondly, we calculate the benefits of using PCSs during the first year based on the saved man-hours. The calculation of cost and benefits are conducted both for quotation process and for engineering phase. In this research, we focus on the saved man-hours in calculating the ROI in one case company. Finally, we discussed how PCS can influence the ROI of the project both in quotation and engineering phase.

2. LITERATURE REVIEW

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

Only few researchers have addressed cost factors in relation to product configuration [2]. 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 [10], [16], [25]–[33], [17]–[24]. The costs of configurators discussed in [10], [29] includes software licenses (costs of buying the software and annual licenses costs), as well as internal and external hours used for modelling, programming and implementing the configurator. The costs are partly the initial costs of making the configurator and partly the annual costs of maintaining and operating the configurator [34]. However, there are still some hidden costs, for example, the time for people to learn and use the system, but these hidden costs could be measured as the man-hours [35]. However, none of the researchers have investigated the factors which are influencing the cost-benefit analysis and if PCS using in different phases of the projects (quotation, engineering, production) have different ranges of ROI [36]. In this research, we only focus on the saved man-hours which is the main and quantified indicator to calculate the ROI to fill a knowledge gap in the literature.

The financial benefits of PCS projects needs be clear before any investments, and cost evaluation is important from the initiation phase [37]. Cost-benefit analysis is used to compare the expected costs and benefits for different scenarios and the results from a variety of actions [38].

2.2. Return on investment for PCS

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 [39], and has been used to determine the profitability of PCS projects [15]. In this context, the performance measure "return on investment "(ROI) is commonly used for evaluating different investments [40]. The ROI is calculated as shown Equation (1) [40].

$$ROI = \frac{\text{Total benefits} - \text{Cost of investment}}{\text{Cost of investment}} \quad (1)$$

Some researchers have applied ROI in relation to product configuration. This includes Barker et al. [19], who discussed the net return of a configurator project; Fleischanderl et al. [41], who reported a configurator project in which the company achieved complete ROI within the first year of operation; Forza and Salvador [21], who described how small enterprises may benefit from configurators, not only through a rapid ROI, but also through competitive advantages; and [15] who used it to determine the profitability of a product configurator project.

3. RESEARCH METHOD

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.

In the current research, the investment, the benefit per process (in man-hours) and the total cost of the project is provided by the company. The amount of saved man-hours before and after using the PCS 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 first year of the project implementation.

In this research, we use case study to evaluate ROI in one ETO (Engineer To Order) company. The company is the leading engineering and design office for heat exchangers, preassure vessels and air coolers related to the oil and gas industry. Calculation will be applied on the most common case – heat exhangers.

The reason for choosing one case company is to provide the in-depth data analysis while accessing data both in quotation and engineering phase including organizational culture are fixed. 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 [42], 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 STUDY

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.

For that reason, the project of heat exchanger development was taken, which is most often ordered by clients. Heat exchangers are typically classified according to flow arrangement and type of construction. The simplest heat exchanger is one for which the hot and cold fluids move in the same or opposite directions in a concentric tube (or double-pipe) construction. In the parallel-flow arrangement, the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end. In the counterflow arrangement, the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends. Alternatively, the fluids may be in cross flow (perpendicular to each other) [43].

Table 1 reports all the annual cost of the specific product to be ordered focusing on the quotation phase and before using PCS. The activities in the quotation phase is divided in calculation, setting plan, and shopping list. Calculating the required man-hours and number if orders/month, we calculate the total annual costs of only quotation process of heat exchanger for the case company.

Table 1. *Annual costs of ordered projects during quotation phase at the case company before using PCS (all costs in euro)*

Activity	Resources	Man-hours	salary (EUR/h)	Costs	Number of orders/month	Cost/month	Number of months	Cost/year
calculation	1	24	15	360	8	2880	11	31.680
setting plan	1	16	15	240	8	1920	11	21.120
shopping list	1	8	15	120	8	960	11	10.560
Total		48		720	8	5760	11	**63.360**

Table 2 reports all the annual cost of heat exchanger to be ordered focusing on the engineering phase and before using PCS. The activities in engineering phase include *detailed calculation, general arrangement, and final drawing.* Again we calculate the required man-hours and number if orders/month, and the total annual costs of the engi-neering process of heat exchanger for the case company.

Table 2. *Annual costs of ordered projects during engineering phase at the case company before using PCS (all costs in euro)*

Activity	Resources	Man-hours	salary (EUR/h)	Costs	Number of orders/month	Cost/month	Number of months	Cost/year
calculation	1	40	15	600	4	2400	11	26.400
general arrangement	1	40	15	600	4	2400	11	26.400
drawings	1	40	15	600	4	2400	11	26.400
total		120		1800	4	7200	11	79.200

Table 3 demonstrates the data related to the initital investment on the PCS software platforms focusing on the licences fees per user, per developer as well as annual maintenance fees.

Table 3. *Costs of PCS software licenses per users and developers (all costs in euro)*

Users' type	cost per user	Numbers of users	Annual cost of maintenance	Total licenses cost
End-users	995	2	17% of the license cost	1.990+ 338.3
developers	5.500	2	17% of the license cost	11.000+ 1.870
Total cost for one year	6.495	4	2208.3	**15.198**

Table 4 illustrates all the figures related to development costs of the PCS project for one particular product. The costs of development include the man-hours used to develop the configurator and the required man-hours to maintain the configurator for the first year after developing PCS.

Table 4. *Costs of PCS development and maintenance at the case company (all costs in euro)*

	Number of resources	Man-hour Cost per hour	Required time	Costs
Development costs	2	17	6 months	36.000
Maintenance costs for the first year (6 months)	1	17	2 days/ month	1.632
Total costs for the first years	37.632			
Total Costs (development + maintenance + licenses) per year	52.830			

Table 5 demonstrates the annual costs of the quotation process for the new ordered heat exchangers after development of the PCS at the case company. The costs are calculated based on the saved man-hours and the cost of the quotation generation for the ordered heat exchanger after developing PCS.

Table 5. *Annual costs of ordered projects during quotation phase at the case company after using PCS (all costs in euro)*

Activity	Resources	Man-hours	salary (EUR/h)	Costs	Number of orders/month	Cost/month	Number of months	Cost/year
calculation	1	24	15	360	8	2880	11	31.680
setting plan	1	8	15	120	8	960	11	10.560
shopping list	1	3	15	45	8	360	11	39.60
Sum		35		525	8	4200	11	**46.200**

Table 6 demonstrates the annual costs of the engineering process for the new ordered heat exchangers after development of the PCS at the case company. The costs are calculated based on the saved man-hours and the cost of the engineering calcalations, arrangements anddrawings generation for the ordered heat exchanger after developing PCS.

Table 6. *Annual costs of ordered projects during realization phase at the case company after using PCS (all costs in euro)*

Activity	Resources	Man-hours	Salary (EUR/h)	Costs	Number of orders/month	Cost/month	Number of months	Cost/year
calculation	1	40	15	600	4	2400	11	26.400
general arrangement	1	24	15	360	4	1440	11	15.840
drawings	1	20	15	300	4	1200	11	13.200
		84		1260	4	5040	11	**55.440**

5. DISCUSSIONS

Table 7 demonstrates the final calculation of ROI based on the cost benefits for the heat exchanger project at the case company in the first year of developing PCS. We need to mention that the first year also includes the development of PCS for 6 months. As demonstrated in Table 7, the ROI is caculated both for the quotation and engineering phases of the heat exchanger project.

Table 7. *Calculation of ROI based on the annual saved man-hours*

	Saved man-hours	ROI in the first years
Man-hours saving in quotation phase	17.160	32%
Man-hour saving in realization phase	23.760	44%
Total Man-hour saving in all phase of the project	40.920	77%

Comparing the ROI in quotation phases and engineering phases demonstrates the higher ROI in the engineering phase and confirms our proposition. The reason can be explained based on the required man-hours for each phases. In majority of the project, the amount of the required man-hours for the engineering tasks are higher compared to the quotation phase. Hence, automating the engineering phase will save more hours compared to quotation phase. Therefore, as it is demonstrated in Table 7, the ROI for engineering activities is higher when developing and using PCS project. Moreover, developing PCS for very complicated products might require more investment for the PCS project for engineering phase. However, this will only influence the ROI in the first year. Hence, we can conclude that in general ROI is higher for engineering phases.

6. CONCLUSION

Conducted analysis showed that the implementation of PCS in engineering companie can be cost-effective, even for the companies in countries with lower engineering salaries. For the purpose of more detailed analysis, it would be useful to check the offers of other configuration platforms, as well as to take into account other products from the production program for which the configurator would potentially be used.

7. REFERENCES

[1] A. Felfernig, *Knowledge-Based Configuration*. Elsevier, 2014.

[2] S. Shafiee, "Conceptual modelling for product configuration systems," Technical University of Denmark, Denmark, 2017.

[3] 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, Newnes, 2014, pp. 73–87.

[4] Bernhardt, *Product customization*. Berlin Heidelberg: Springer Science & Business Media, 2008.

[5] 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.

[6] 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, NY: Palgrave Macmillan, 2006.

[7] A. Haug, S. Shafiee, and L. Hvam, "The costs and benefits of product configuration projects in engineer-to-order companies," *Computers in Industry*, vol. 105, pp. 133–142, 2019.

[8] Y. Wang, J. Wu, R. Zhang, S. Shafiee, and C. Li, "A 'user-knowledge-product' Co-creation cyberspace model for product innovation," *Complexity*, vol. 2020, no. 1, 2020.

[9] A. Felfernig, L. Hotz, C. Bagley, and J. Tiihonen, *Knowledge-based Configuration from Research to Business Cases*. Newnes, NWS, Australia: Morgan Kaufmann, 2014.

[10] 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.

[11] A. Haug, S. Shafiee, and L. Hvam, "The causes of product configuration project failure," *Computers in Industry*, vol. 108, pp. 121–131, 2019.

[12] Y. Wang, J. Wu, L. Lin, and S. Shafiee, "An online community-based dynamic customisation model: the trade-off between customer satisfaction and enterprise profit," *International Journal of Production Research*, 2019.

[13] P. Blazek and K. Pilsle, "Learnings From Setting Up Product Configurator Projects," *Annals of the Faculty of Engineering Hunedoara - International Journal of Engineering*, vol. 15, no. 1, pp. 25–28, 2017.

[14] 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.

[15] 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, pp. 57–69, 2018.

[16] 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.

[17] 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.

[18] L. Ardissono *et al.*, "A framework for the development of personalized, distributed web-based configuration systems," *AI Magazine*, vol. 24, no. 3, pp. 93–110, 2003.

[19] 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.

[20] 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.
[21] 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.
[22] 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.
[23] 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. 02, pp. 197–206, Apr. 2011.
[24] 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.
[25] 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.
[26] 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.
[27] 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.
[28] 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.
[29] L. Hvam, "Mass customisation of process plants," *International Journal of Mass Customisation*, vol. 1, no. 4, pp. 445–462, 2006.
[30] 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, pp. 329–338, 2013.
[31] T. D. Petersen, "Product Configuration in ETO Companies," in *Mass customization information systems in business*, T. Blecker, Ed. Igi Global, 2007, pp. 59–76.
[32] J. J. Sviokla, "An Examination of the Impact of Expert Systems on the Firm: The Case of XCON Impact of Expert Systems on the Firm: The Case of XCON," *MIS Quarterly*, vol. 14, no. 2, pp. 127–140, 1990.
[33] 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.
[34] T. Pisello, "IT Value Chain Management – Maximizing the ROI from IT Investments," Standish Report, 2003.
[35] P. R. Massingham and R. K. Massingham, "Does knowledge management produce practical outcomes?," *Journal of Knowledge Management*, vol. 18, no. 2, pp. 221–254, 2014.
[36] S. Shafiee, C. Forza, A. Haug, and L. Hvam, "Merging Commercial and Technical Configurators," *8th International Conference on Mass Customization and Personalization – Community of Europe*, pp. 250–255, 2018.
[37] 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.
[38] A. C. Haddix, S. M. Teutsch, and P. S. Corso, *Prevention effectiveness: a guide to decision analysis and economic evaluation*. Oxford University Press, 2003.
[39] 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.
[40] J. J. Phillips, *Return on Investment in Training and Performance Improvement Programs*. Routledge, 2012.
[41] G. Fleischanderl, G. E. Friedrich, A. Haselböck, H. Schreiner, and M. Stumptner, "Configuring large systems using generative constraint satisfaction," in *IEEE Intelligent Systems and Their Applications*, 1998, vol. 13, no. 4, pp. 59–68.
[42] J. Meredith, "Building operations management theory through case and field research," *Journal of Operations Management*, vol. 16, no. 4, pp. 441–454, 1998.
[43] F. P. Incroper, D. P. Dewitt, T. L. Bergman, and A. S. Lavine, *Fundamentals of heat and mass transfer*. USA: John Wiley & Sons, 2011.

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