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Myrodia, Anna; Kristjansdottir, Katrin; Hvam, Lars

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Impact of product configuration systems on product profitability and costing accuracy

Anna Myrodia, Katrin Kristjansdottir, Lars Hvam

Abstract. This article aims at analyzing the impact of implementing a product configuration system (PCS) on the increased accuracy of the cost calculations and the increased profitability of the products. Companies that have implemented PCSs have achieved substantial benefits in terms of being more in control of their product assortment, making the right decisions in the sales phase and increasing sales of optimal products. These benefits should have an impact on the company's ability to make more accurate cost estimations in the sales phase, which can positively affect the products' profitability. However, previous studies have not addressed this relationship to a great extent. For that reason, a configure-to-order (CTO) manufacturing company was analyzed. A longitudinal field study was performed in which the accuracy of the cost calculations and the products' profitability were analyzed before and after a PCS was implemented. The comparison in the case study revealed that increased accuracy of the cost calculations in the sales phase and consequently increased profitability can be achieved by implementing a PCS.

Keywords: Product configuration system, Cost calculation accuracy, Product profitability, Benefits of product configuration systems, Longitudinal case study

1. Introduction

In today's business environment, companies are forced to offer customized solutions without compromising delivery time, quality and cost [1]. To respond to these challenges, mass customization strategies have received increasing attention over the years, from practitioners and researchers. Mass customization refers to the ability to make customized products and services that fit every customer through flexibility and integrations at cost similar to mass-produced products [2]. Utilizing product configuration systems (PCSs) is one of the key success factors in achieving the benefits of the mass customization approach [2,3].

PCSs are used to support design activities throughout the customization process, where a set of components and their connections are pre-defined and where constraints are used to prevent infeasible configurations [4]. Companies that have implemented PCSs have achieved numerous benefits such as shorter lead times, more on-time deliveries, improved quality, less rework and increased customer satisfaction [1,5–7]. In addition, the supportive function of the PCS enables improved decision making in the early phases of engineering and sales processes [8]. Furthermore, the system can be used as a tool that allows the salesperson to offer custom-tailored products within the boundaries of standard product architectures, thus giving companies the opportunity to be more in control of their product assortment [1]. It can be assumed that these benefits will have an impact on the company's ability to increase the accuracy of the cost calculations in the sales phase, which can positively affect the products' profitability. However, the link between the implementation of a PCS and the effects on the company's

ability to increase the accuracy of the cost calculations in the sales phase and consequently increase the products' profitability has not received much attention from researchers [9]. Thus, the focus of this study is assessing the impact of implementing a PCS on a company's ability to make accurate cost calculations in the sales phase and products' profitability. Aiming to investigate these effects, the following propositions were developed:

Proposition 1 *The accuracy of the cost calculations in the sales phase is increased by utilizing a PCS.*

Proposition 2 *Product profitability is increased by utilizing a PCS.*

To test the propositions, a longitudinal field study was performed in a configure-to-order (CTO) company. In 2009, an analysis of product profitability and the accuracy of the cost calculations in the quotations generated in the sales phase was conducted. The results indicated that the performance of the sales processes could be significantly improved by implementing a PCS. That recommendation was adopted by the company; thus, a PCS was developed and implemented in 2011. Although the company has used the PCS since 2011, some salespersons still have not accepted the system and therefore generate quotations outside the PCS. This behavior provides an opportunity to compare quotations generated with the PCS and without the PCS over a 4-year period after the implementation. The results indicate that the quotations generated in the PCS have more accurate cost calculations, and consequently, the profitability of the products sold via the PCS is higher.

2. Literature review of the benefits of utilizing PCSs

In this section, the theoretical background of the present research is reported. To find relevant articles, a literature review was performed in the research area of PCSs. The focus of the literature review was identifying the main benefits and challenges of implementing and utilizing PCSs. Several research groups have conducted extensive studies in this field.

2.1. Benefits

First, the benefits identified by utilizing a PCS are discussed. As the focus of this study was to assess the impact of implementing a PCS, quantitative data were required. The results from the literature study are presented in Table 1. The benefits discussed in the literature are listed, and the articles discussing the benefits are listed in the second column. The last column specifies whether the impact of the utilization of a PCS was measured and shows quantitative data from the benefits identified.

Table 1. Benefits obtained from implementing PCSs.

Benefit	Authors	Measurement
Reduction in lead time for making specifications	[1,5,7,10–16]	From 5–6 days to 1 day [10] The real working time for preparing offers and production instructions is near zero [11] 75–99.9 % reduction in the quotation lead time [7] 15–25 days to 1–2 days [12]

Reduction in lead time for delivering the product	[11,14–18]	Delivery time reduced from 11–41 days to 1 day [11]
Saved work-hours	[1,10,12,15–19]	The engineering hours for creating quotations were reduced from 5 work-weeks to 1 to 2 work-days [12] Throughput cycle was reduced from 6 days to 1 day [19]
Increased quality of product information/specifications	[1,6,10,12–16,18–23]	Reduction to almost zero of errors in configurations released by the sales office [1] Increased level of correctness of product information to almost 100% [10] Specifications quality improved from 60% to 100% manufacturable [19]
Improved product quality	[21,24]	N/A
Improved on-time delivery	[1,10,25]	N/A
Increased employee productivity	[1,14,22]	N/A
Lower production costs	[11,21]	Fixed production costs were reduced by 50% and variable costs by 30% [11] Reduction from 30% to less than 2% in the number of assembly errors [11]
Improved efficiency in aftersales	[11]	Time for replacement was reduced from 5–6 hours to 20–30 minutes [11]
Improved knowledge management	[1,6,11,22,26]	N/A
Improved control of product variants	[1,10,20,25]	N/A
Reduced product lifecycle cost	[27]	PCS supporting the complete configuration process may reduce the configuration cost up to 60% over the product lifecycle [27]
Increased customer satisfaction	[21]	N/A
Improved customer relationships/communications	[1,10,13,20,22,26]	N/A

Summarizing the findings from the literature review, the implementation of a PCS provides various benefits to companies, in terms of resource reduction, decreased lead time, better communication with customers and improved product quality (Table 1).

There is a lack of empirical evidence that measured the impact of implementing PCSs on improved profitability and more accurate cost estimates. The present work contributes to the literature by providing a longitudinal field study that compared the economic performance of the products and the accuracy of the cost calculations before and 4 years after a PCS was implemented in an industrial manufacturing company.

2.2. Challenges of implementing a PCS

In this section, the literature focuses on the challenges and practical implications of implementing PCSs. The challenges refer not only to the scope of the PCS but also to the implementation and utilization of the system by employees and its acceptance as part of their daily work routine. The following table summarizes the main challenges identified in the literature.

Table 2. Challenges associated with utilizing PCSs.

Challenges	Authors
Supporting customers' needs in the configuration process	[27,28]
Product modeling and data acquisition	[1,6,10,27]
Errors in the configuration process	[6]
Documentation and maintenance configuration model	[6,10]
Change management	[1]

The implementation of PCSs is not free of challenges during the process. This is explained in the difficulties faced by the users and the developers of PCSs related to supporting customers' needs in the configuration process, product modeling and data acquisition, errors in the configuration process, documentation and maintenance and challenges regarding change management and acceptance of the system as part of the work procedures.

3. Research method

This research was conducted as a longitudinal field study, where the impact of implementing PCSs was analyzed, focusing on the accuracy of the cost calculations and profitability. The research was conducted as a collaboration between the Technical University of Denmark (DTU) and the case company over the 2009–2014 period and included multiple observations of the change process. The research team monitored the implementation and the impact of the PCS from the beginning until the PCS was fully integrated into the company's business processes. The company was selected as it is highly representative of medium-sized CTO companies that provide highly customized products and operate globally.

A longitudinal field study was selected as the research method for this work as this design allows the team to make real-time and in-depth observations of the change process and development in organizations [29,30] and specifically in this case, the process of implementing and utilizing a PCS over a 4-year period. Longitudinal field studies are a special type of case study in which the phenomenon is studied in its natural setting over time using multiple observations where the change process is observed as it unfolds in real time [31]. This type of study is most suitable when the aim is to explore new ground as the study design allows the researcher to be close enough to the studied phenomenon to discover the causal links among events and constructs [31].

Based on the nature and requirements of longitudinal field studies, this study was designed to investigate and analyze the existing problem of the lack of accuracy in cost calculations and product profitability. The unit of observation [32] was the different projects sold during the 2009–2014 period. The data required for the analysis included the estimated costs for each

project sold and the actual cost. Data was collected about the salespersons and the quotations they generated at the company by using Excel spreadsheets and PCS. All data sets refer to 2009, before the PCS was implemented, and then to the 2011–2014 period when a PCS was used at the company. The data set for the analysis was extracted from the company's internal database and verified with specialists at the company.

4. Case study

4.1. Background of the case company

The case company analyzed in this study is a Scandinavian company in the building industry, which manufactures pre-made structural elements for buildings and provides installation services. The company is highly representative as a medium-sized company, which includes manufacturing, installation and maintenance in its business processes. In 2014, the company had around 100 employees and yearly turnover of approximately €17 million. In that year, the company sold 168 projects, and the average turnover per project was therefore €106,158. The company's product portfolio consists of six product families, of which five are standard products and one special.

In 2009, the process of generating quotations in the sales phase and the accuracy of the cost calculations were analyzed. The analysis revealed that the company's methods for accurately calculating costs were inadequate and affected the products' profitability. The results also indicated that the company's current procedure of using Excel spreadsheets to calculate the costs led to numerous errors, which were traced back to human mistakes. Based on this initial analysis, the company decided to invest €150,000 in order to develop a PCS to improve the process of generating quotations in the sales phase. The PCS used at the company was commercial configuration software, which builds on constraint propagation.

The PCS was developed from 2009 to 2010, and by the beginning of 2011, the company had developed a PCS able to handle most of the quotations in the sales phase. Only special products, which are categorized as non-standard solutions or engineered solutions, were not included in the system. Although the company developed and implemented a PCS to support the sales process, organizational resistance to using the system and changing current work procedures resulted in some salespersons still using the Excel spreadsheets to calculate costs for the quotations in the sales phase.

In this study, the impact of utilizing the PCS on the company's ability to make accurate price estimates for the quotations and product profitability was assessed. First, the company's overall performance is analyzed before the system was implemented in 2009 and 4 years after the implementation during the 2011–2014 period. Then the accuracy of the cost calculations and products' profitability in the quotations generated by using the Excel spreadsheets and the PCS were compared.

4.2. Analysis of the company's performance before and after implementation of the product configuration system

To compare the overall performance before the PCS was implemented (2009) and after the implementation (2011–2014), the contribution ratio (CR) is calculated for each project that was carried out at the company within the timeframe of this research. The CR is calculated as the ratio of the sales price and the contribution margin (CM), where the CM is the difference between the sales and the cost price. The cost prices of the projects are calculated as the sum of

expenses, including construction site, subcontractors, materials and salaries. The formulas for the calculations of the CR and the CM are as follows [33]:

$$CR = CM / Sales\ Price \quad (1)$$

$$CM = Sales\ Price - Cost\ Price \quad (2)$$

The deviation in the CR is calculated as the actual CR (calculated after the project was completed when all expenses are known) minus the estimated CR (calculated in the sales phase when the cost is estimated). The formula for calculating the deviation of the CR as follows:

$$DEV_{CR} = CR_{actual} - CR_{estimated} \quad (3)$$

If the real cost of the project is higher than the estimated cost, it results in negative deviation of the CR. Respectively, if the real cost of the project is less than the estimated, it results in positive deviation in the CR. Any deviation in the CR is something companies must be aware of. If the cost is overestimated, the company might lose the customer, and if the cost is underestimated, then revenue is lost.

The projects used for the comparison are from 2009, when only Excel spreadsheets were used to calculate the cost, until 2014. For the 2011–2014 period, the cost calculations were either performed in the PCS or by using Excel spreadsheets. Due to organizational resistance, not all salespersons used the PCS. In Table 3, the company's overall performance for 2009 and the 2011 to 2014 period is shown in terms of number of projects sold, the deviation in the CR and the average profitability.

Table 3. Overall analysis of the company's performance before the PCS was implemented (2009) and after (2011–2014).

Year	*No. of projects*	*Average* DEV_{CR}	*Average CR per project*
2009	55	–1.5%	25.0%
2011	117	–3.5%	27.2%
2012	90	–1.1%	28.5%
2013	116	–1.0%	28.2%
2014	168	–0.8%	29.0%

The analysis showed that the average CR steadily increased from 25.0% in 2009 to 29.0% in 2014. The implementation of the PCS was aimed to improve the company's CR by increasing the accuracy of the cost calculations in the quotations and thus the profitability of the projects. Furthermore, an additional functionality was included in the PCS that allowed the salespersons to set the desired CR for the project under question from an early stage of the sales process in order to make it easier to reach the goal.

Deviations in the CR also show positive improvements over the period as the average deviation was improved from –1.5% in 2009 to –0.8% in 2014. However, in 2011, the first year the PCS was utilized, the deviations in the CR increased considerably. This increase in deviations can be traced to the fact that the system had not been fully tested before the implementation and the users of the system lacked training. However, as the users became more experienced in using the system and errors were fixed, the PCS started providing valuable results.

This analysis indicates that the calculations are now more precise than before the implementation of the PCS and the company is moving closer to the targeted CR, and, consequently, the products' profitability is increasing. The results also highlight the importance of properly

testing the system and training employees before the system is launched and fully functioning to avoid costly mistakes and to avoid resistance to using the system due to a lack of confidence.

4.3. Comparison of cost estimations and profitability between Excel and PCS

In this section, the yearly turnover, the CR of the projects and the deviations of the CR are analyzed and compared in terms of whether the initial quotation created during the sales phase was generated by the Excel spreadsheets or by the PCS. For this analysis the same data is used as explained in section 4.1 and 4.2. The data acquired from the company's database is used to calculate the turnover and the CR of the projects sold both for the quotations generated through the PCS and Excel. This comparison is possible because the PCS has not been accepted by all salespersons due to organizational resistance. Some still use Excel spreadsheets to generate quotations. The main reason is the lack of change management initiatives and the system being launched before it was fully tested, which resulted in some employees sticking to their old work habits [1].

4.3.1. The contribution to yearly turnover

To increase the understanding of to what extent the PCS is used at the company, the yearly turnover for the projects was compared based on whether the quotation was generated with the PCS or the Excel spreadsheets.

In 2011, the first year the PCS was utilized in the company, the turnover for the products' quotations generated with the PCS was higher than the ones created with Excel spreadsheets. However, in 2012 the turnover for the products' quotations generated by using Excel spreadsheets was higher. In the first year the system was running, the lack of training and errors in the system affected its functionality. However, in 2013, the quotations generated with the PCS contributed more to the yearly turnover, and in 2014, this difference increased even more, indicating that the salespersons were using the system to a greater extent. Fig. 1 shows the yearly turnover for the quotations created in Excel and by using the PCS.

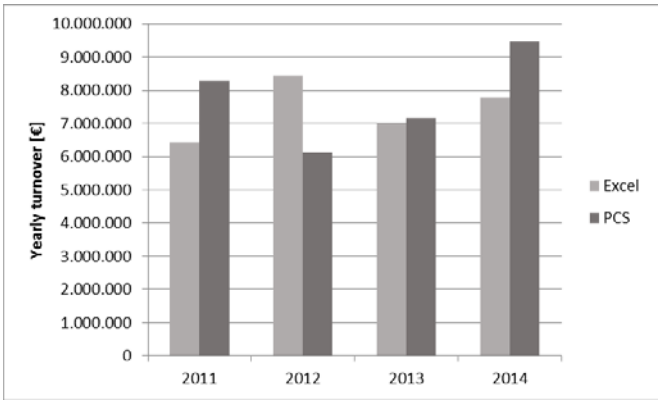

Fig. 1. Comparison of turnover generated for quotations created in Excel and PCS.

However, no clear trend was identified in the comparison. As can be seen in Fig. 1, in 2012, the projects handled by the salespersons with Excel spreadsheets contributed more to the company's turnover although the PCS had already been implemented. Some salespersons were

reluctant to use the PCS in their working processes, as they still used Excel spreadsheets for calculating costs and generating quotations. Second, lack of training and errors in the system in 2011 might have given some salespersons the wrong impression of the usability of the system, which resulted in them not using the PCS in the following year. In detail, in 2011, 52% of the projects were handled with Excel spreadsheets to generate quotations, which corresponds to 47 out of 90 projects. The 2011–2012 period was the initial introduction of the PCS at the company, and the PCS did not include all products at that point; therefore, utilization was by definition limited. During the trial period, the turnover contributed by the projects handled in Excel was higher than the turnover from the projects handled in the PCS, but this changed significantly in the following 2 years. Thus, in the 2013–2014 period, when the company took greater advantage of the PCS, and its utilization was strongly established, the turnover of the projects worked out by using the PCS outnumbered the ones generated with Excel spreadsheets.

Overall, by comparing the yearly turnover of the projects handled through Excel spreadsheets and the PCS, no clear conclusion was reached. Thus, the next step of the analysis focused on identifying and comparing the CR for products sold via Excel and PCS.

4.3.2. Comparison of project profitability

To compare the profitability of the projects, the CR was used as it represents the ratio between sales prices and the CM, and a good indicator of project profitability. As previously explained, the company's goal for all projects is a CR of 30%, as a result of a strategic decision made in 2009 to increase the CR from 25% to 30%. The implementation of the PCS was aimed to reach the targeted CR of 30% for the projects. The analysis of the overall company's performance (Table 3) showed how the CR has increased since 2009. However, to confirm that this can be traced to the implementation of the PCS, a comparison of the CR of the quotations made by using the PCS and Excel spreadsheets was performed. In Fig. 2, the actual CR (calculated based on the actual cost of the projects) is illustrated for the quotations created with the PCS and Excel.

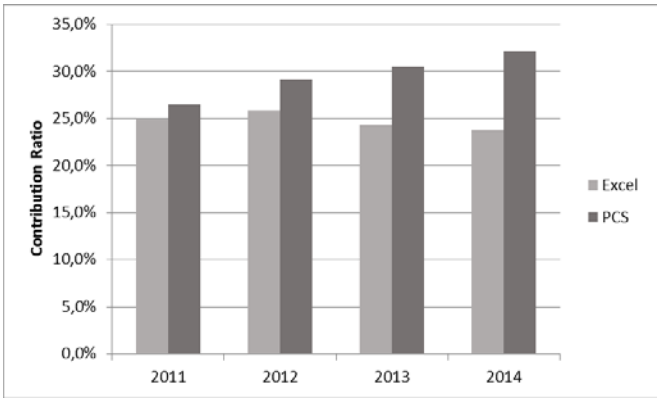

Fig. 2. Comparison of CR for salespersons using Excel and PCS.

Salespersons who used the PCS contributed a higher CR than those who used Excel spreadsheets. Furthermore, the gap in the CR increased between the salespersons who used the Excel spreadsheets and those who used the PCS. In 2014, the average CR was 29.0%; salespersons who used the PCS had an average CR of 32.1% while salespersons who used Excel spread-

sheets had 23.8%. In other words, the salespersons who used the PCS achieved a goal of 30%. The increasing gap between the CR for the quotations generated in the two systems can also be explained as a result of the increased utilization of the PCS and the company's effort to update prices in the PCS instead of the Excel spreadsheets. Finally, special products were not included in the PCS; therefore, to calculate the costs, Excel spreadsheets were always used. Although those products were not included in the calculations for the quotations made in Excel presented in Fig. 2, they did not contribute significantly to the average CR. For example, for 2014 they affected the CR for the quotations created in Excel by only 0.2%. Therefore, the lower CR cannot be traced to special orders. This result confirms the second proposition formulated in this study: Product profitability increased when the projects are handled through a PCS.

4.3.3. Comparison of the accuracy of the cost calculations

To compare the accuracy of the cost calculations generated in the PCS and Excel spreadsheets, the DEV_{CR} is calculated. The results are shown in Fig. 3.

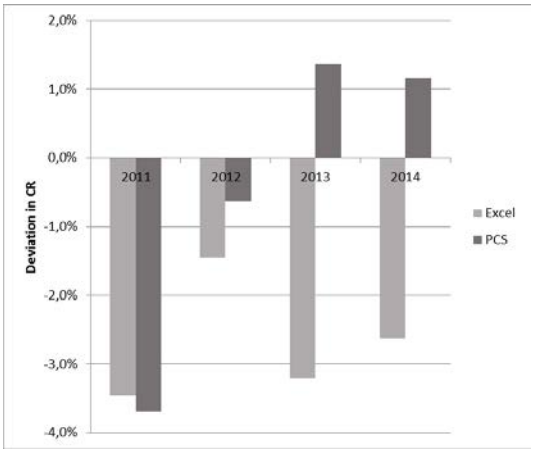

Fig. 3. Comparison of deviations in CR for salespersons who used Excel and PCS.

The CR showed less deviation for the products for which salespersons used the PCS than the CR for the products for which salespersons used Excel spreadsheets, with the exception of 2011. The deviation in the CR for the PCS in 2011 can be explained as a result of insufficient testing and a lack of training, which affected the performance in the first year after the implementation. In the following year, 2012, there was a significant reduction in deviations for quotations created via Excel spreadsheets and, mainly, for the ones created through the PCS. Moreover, in 2013 and 2014, the deviations in the quotations created by the PCS were positive (1.4% and 1.2%, respectively), while the deviations for the cost calculations generated with the Excel spreadsheets were negative and still quite high (–3.2% and –2.6%). Another possible explanation for the increasing gap between the CRs is the more complete cost calculations via the PCS than Excel spreadsheets. All parts required for every product were included in the PCS, while when the cost estimate was created in Excel spreadsheets, the salesperson might forget to include all of them. As a result, the estimated cost did not include all required parts and was lower than the actual cost, which led to the negative deviation in the CR. The analysis of the performance of the salespersons who used Excel and the PCS therefore indicates that the

PCS affected the accuracy of the cost estimates and the CR positively, which supports proposition 1.

5. Discussion

This work focused on measuring the benefits of implementing a PCS in a CTO manufacturing company. To measure the benefits, the CRs of the products handled in Excel and the PCS were calculated and compared. The comparison revealed that the CR of the products handled via the PCS was higher than the ones in Excel. Taking into account the increase in the CR from 25% to 29%, which is equivalent to €654,000 per year, and the cost of the development of the PCS was €150,000, the annual return on investment (ROI) was 336%. In addition, the accuracy of the quotations generated by the PCS was higher than those generated in Excel.

Regarding the salespersons who were still using the Excel spreadsheets while the PCS was implemented, reasons similar to those identified in the literature review were reported [1,6,10,27]. In detail, the most experienced salespeople in the company were those who were still using Excel in 2014 to generate quotations. They stated that the PCS did not add value to their daily routine as long as it was not updated for the user interface and functionalities and included all relevant products. Therefore, the PCS had to be upgraded with all functionalities in order to be fully accepted and adopted by all employees and enable the company to seize the full benefits of the PCS.

To improve the company's general performance, several factors were identified, which could help the company reduce even further the deviations in the CR and increase the overall profitability of the products. For instance, the company intends to implement a checklist at the end of each configuration in order to ensure that all required information is gathered during the sales phase and is up-to-date. Implementing the checklist will reduce the number of errors made during the sales process. Furthermore, the company plans to increase standardization in their product range, by moving further to modular-based product designs. Regarding the further development of the PCS, the company has decided to invest €140,000 to include more products. Finally, to implement an organizational change [1] and boost utilization of the PCS, all new employees are trained to use only the PCS; thus, the Excel spreadsheets will become obsolete.

6. Conclusions

The aim of this case study was to measure the impact of utilizing a PCS on product profitability and the accuracy of cost estimates. The study resulted in significant improvements in the CR of products sold through the PCS due to the accuracy of the cost calculations. The results from the longitudinal case study confirmed the propositions. In detail, the improved accuracy of the cost calculations and the increased profitability of the products sold via the PCS were demonstrated. The quotations generated by the PCS and Excel for the 2011 to 2014 period were compared, when the PCS had been implemented and was used to its full potential. The analysis led to the conclusion that the contribution of the PCS is noteworthy, as the performance of the products included in the PCS improved in terms of more accurate cost estimates and improved profitability (propositions 1 and 2). This could be explained by the fact that the data used in the PCS is updated and all possible solutions are validated before making an offer, the generated quotations include fewer errors and more accurate price estimates than the quotations for products not included in the PCS. However, this study also highlights the importance of fully testing

a PCS before making it operational. To this end, as can be seen from the results, the implementation had a negative impact in the first year due to insufficient testing. In addition, the challenges of scoping and utilizing a PCS are discussed in the literature and the empirical evidence here.

This research is the first step in exploring the impact of a configurator on product profitability. Thus, more cases need to be examined, to compare the profitability between projects going through the PCS and outside it and salespersons' performance before and after the implementation of a PCS. By examining more cases, a deeper understanding can be gained, and a more detailed explanation of the correlation between the configuration tools and product profitability can be provided. In this paper, empirical evidence was provided by only one case company. However, the impact registered in this company indicates that there could be significant impacts from implementing a PCS, which have not been previously discussed in the literature. The increase in the CR of the products is important, and the PCS brought significant value to the company. Therefore, this requires further research and additional cases to confirm the underlying correlation between a PCS and an increase in profitability. Future research should include investigation of other benefits of utilizing a PCS, such as its impact on an increase on sales.

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