Impact on cost accuracy and profitability from implementing product configuration system – A case-study

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Abstract. This article aims at analyzing the impacts from implementing a product configuration system (PCS) on company's profitability and improved cost estimations in the sales phase. 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. Those benefits should have a direct impact on improved profitability in terms of increased contribution ratios and more accurate cost estimations used to determine the price in the budgetary quotations. As the literature describes, there are various benefits from implementing a PCS, however the effects on the company's profitability have not been discussed in detail. This study analyzes the impact from implementing a PCS on the accuracy of calculations in the quotations and the impact on the relative contribution ratios of products. For that reason, a configure-to-order (CTO) manufacturing company has been investigated. A longitudinal study is performed where both the accuracy of the cost calculations and the profitability is analyzed before and after the implementation of a PCS. The comparison reveals that increased profitability and accuracy of the cost estimation in the sales phase can be achieved from implementing a PCS.

1 INTRODUCTION

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

PCSs are used to support design activities throughout the customization process, where a set of components along with their connections are pre-defined and where constrains are used to prevent infeasible configurations [4]. This is one of the reasons why configurations systems are considereded to be among the most successful applications of artificial intelligence [5].

Once implemented, the PCS usually supports the sales and engineering processes in various dimensions, which can lead to numerous benefits such as; shorter lead-times, more on-time deliveries, improved quality of the product specifications, less rework and increased customer satisfaction. Besides, its supportive function PCS enables improved decision making in the early phases of engineering and sales processes [6]. 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, thereby giving companies the opportunity to be more in control of their product assortment [7]. As the various benefits are described from implementing a PCS, it can be concluded that those benefits will have direct impact on the company's profitability in terms of increased contribution ratios and more accurate cost estimations in the sales phase. However the link between implementing a PCS and its effects on the company's profitability has not received much attention from researchers, even though it is one of the most critical factors during the planning phase of such a system. Ergo this article focuses on assessing the impact of the implementation of a PCS on companies' profitability by analysing the accuracy of the cost calculations in the sales phase and the profitability of the products in terms of their contribution ratios. Based on this, the following propositions are developed:

Proposition 1 *The accuracy of the cost calculations in the quotations is increased by the implementation of a PCS.*

Proposition 2 *The contribution ratio of products is increased when they are included in a PCS.*

Aiming to investigate these effects, a longitudinal case study was performed. In 2009, an analysis of the product's profitability and accuracy of the cost calculations in the quotations generated in the sales phase was conducted. The results from that analysis indicated that the performance of the sales processes could be improved by the implementation of a PCS. That recommendation was adopted by the company; hence a PCS was developed and implemented in 2011. Three years later, the same analysis was performed in order to determine the impacts on the company's profitability that could be related to the implementation of the PCS. The comparison of the results before and after the implementation of the configurator is assessed and discussed in relevance to the propositions.

This paper is structured in 5 sections. In section 2 the relevant literature will be analyzed in terms of PCSs and the benefits that can be achieved from implementing such a system. In section 3 a case study will be presented where the influence on company's profitability and the accuracy of the cost calculations from implementing a PCS will be analyzed. Then, in section 4 the conclusions from the case study are discussed. Finally, in section 5 discussion about the findings of this research work and future research are presented.

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2 LITERATURE REVIEW

In this section the theoretical background of the present research is reported. In order to find the relevant publications a literature review has been performed in the research area of PCSs.

Forza and Salvador have performed extensive research in this field. The authors present a case-study of an CTO manufacturing company, that identifies the benefits of the implementation of a product configuration tool [8]. The benefits discussed are reduction of delivery time, improved customers' relationships and elimination of errors in Bill-Of-Material (BOM). They quantified the impact that the use of a configuration tool has on lead time, as reduction of manned activities in the tendering process (tendering lead-time from 5–6 days to one day). In addition to that, the errors in the products' BOM, misunderstandings between salespersons and customers are eliminated, while at the same time the level of correctness of product information has been increased, reaching almost 100%. In a related study [7], the authors present a case-study of a manufacturer, who's production strategy is based on customers' orders. After the implementation of a product configurator, one of the benefits identified is reduction to almost zero of the errors in the configurations released by the sales office, in addition to savings in man-hours. There have also been noted significant benefits in production, including manufacturing and assembly processes, due to the fact that by using the configuration tool correct information are received in the production. Furthermore, there has been an increase in technical productivity, both regarding product documentation release and design activities.

To this end, the benefits of using a PCS in the sales process are further investigated [9]. One of the main advantages discussed is that the configuration tool describes the possible configurations of the product in a way that they are simple and understandable by the customer. In that way, it can be ensured that there are no contradicting requirements, no missing specifications and that product configurations produced are valid. Moreover, since the configurator deals with real time information, it helps reducing dialogue time between salespersons and customers. Finally, it is highlighted that any kind of miscommunication between the salespersons and the customers is eliminated and possible errors are reduced. The reason for that is a possible source of errors in the quotations due to the sales personnel lack of technical knowledge.

The use of a product configurator and its effect on product quality is discussed by Trentin et al. [10]. The authors performed a survey in order to verify the relationship between the use of a configurator and the quality of products. The results show a positive effect on product quality by using a product configurator.

Haug et al. [11] discuss possible development strategies for product configurator and evaluate the concluding benefits. Advantages identified are, firstly, the convenience of evaluating information included in the configurator software before implementation and ease of altering implemented product information. Facilitating the communication between product experts and configurator software experts is essential in order to build a configuration tool. This results in minimizing use of resources on documentation work and handovers of information, and rapid implementation of gathered information. The benefits realized are both fewer chances of misunderstandings and errors, and faster processes. Haug et al. [12] performed another study in 14 ETO companies, where the impact of implementing a PCS on lead times is quantified. The results indicate significant improvement for the companies, as it has been measured 75% to 99.9% reduction of quotation lead time.

Another case study performed by Hvam [13] discusses and quantifies the impact from the implementation of a PCS in the electronics' industry. The main benefits from the use of configuration tools are considerably lower costs for specification processes and production. The reason for that is that when specifications are generated in the PCSs, the actual working time for preparing offers and production instructions tends to be near zero. The benefits in that case-study are quantified and show that the fixed production costs have been reduced by 50%. Additionally, the variable production costs have been reduced by 30%. On top of that quality has been improved, and is realized as a reduction from 30% to less than 2% in the number of assembly errors, as well as delivery time has been reduced from 11 – 41 days to one day. After-sales services and installation are also positively affected by the configurator. For instance, the time for replacing a battery has been reduced from 5–6 hours to 20–30 minutes.

Hvam et al. [14] performed another case measuring the impact of implementing a PCS in the ordering process of a CTO manufacturer. It is noted that only a 0.45% of the specification process time is value adding. As a result the non-value adding time spent on making the specifications can be reduced by the use of a configurator. By automating the process fewer errors occur, the productivity of employees is improved and the quality of information and documents is increased. That is due to both reducing the standard deviation of the duration of the processes and avoiding errors in quotations.

Similarly to the previous, another case-study is performed by Hvam et al. [15] in an ETO provider of cement plants. The benefits of the implementation of an IT-supported product configuration in the quotation process of complex products are aligned to those discussed above. In detail, a reduction in lead time from 15-25 days to one-two days for the generation of quotations is noted. An increase in the quality of quotes as it is made possible to optimize the cement plants satisfying better the customer's needs, and making less errors in the specifications made in the PCS. Resources consumption for making quotations is reduced in the engineering department from five man-weeks to one to two man-days.

Aldanondo et al. [16] identify the main benefits as the reduction of cost and cycle time for highly customizable products. That is due to the fact that without the support of PCSs iterative procedures occur in sales and design processes. These activities result in generating longer cycle time and increasing costs.

Slater [17] analyses the benefits of a web-based configurator in CTO environments. By using a PCS the company is able to offer the right product from the very beginning to each customer. The PCS assists the sales personnel to have an overview of the valid configurations and, therefore, avoid mistakes in the communication with the customers. This results in eliminating re-works on the customers' order. The same knowledge embedded in the configurator is used to provide unique manufacturing instructions and to make the rules for the correct configuration accessible to the engineers.

Gronalt et al. [18] outline the benefits of the implementation of a PCS, such as personalized customer support, representation of knowledge and distributed reusability of consolidated product configurations. To this end, Hong et al. [19] discusses the use of a configurator so as to reduce the information and attributes used to configure a product variant in One-of-a-kind production (OKP).

Fleischanderl et al. [20] provide empirical evidence showing that a configurator supporting the product development and production process can reduce the cost of the product's life cycle up to 60%.

The implementation of a PCS in the sales and marketing process has direct effects, such as number of errors, pricing, accuracy, time and cost to reworks, time to validate, reduce order cycle time, improve salespersons' morale, improve customers' satisfaction [21].

Empirical evidence from a built-to-order manufacturer claim benefits such as increase on customer satisfaction, lower costs and higher productivity. In addition to these, an increase in the technical accuracy of orders entering manufacturing processes is noted, which also leads to cost and errors' reduction [22].

Tenhiala and Ketokivi [23] performed a survey in make-to-order (MTO) manufacturing companies and found support to the hypothesis that the use of product configurator software in MTO production processes is positively associated with product conformance. Additional findings indicate that in general the use of configuration management practices in MTO production processes is positively associated with product conformance and delivery performance, among custom assemblers and producers.

Another problem that product configurators should focus on, according to Blecker et al. [5], is the customer perspective. They claim that designers of configurators mainly concentrate on the back-end technical aspects. By process simplification and personalization the wrong interpretation of the customer requirements by the supplier can be avoided. PCSs can therefore be beneficial both for the sales and engineering processes.

Tiihonen et al. [24] conduct a survey in Finish manufacturers with modular-based products. Their findings indicate that in extreme cases 80% of the sales specifications are either incomplete or inconsistent. At the same time, less than 20% of the total working time in the order processing is used for value-adding work. By implementing PCSs there is a reduction to the number of errors related to quality and to quality costs. Moreover, the sales' specification produced by the configurator can be directly used as an input for production, as it will not contain errors. Finally, the configuration can assist the representation of products and product families that are often differentiated in different market areas, and also the transfer of up-to-date product configuration knowledge to the sales units and to enforce its proper use.

Summarizing the findings from the literature review, it can be seen that the implementation of a PCS provides various benefits to the manufacturers, in terms of resources' reduction, reduction of lead time, better communication with customers and product quality. However, there is a lack of empirical evidence on quantifying the impact of the use of a product configuration tool on improved profitability and more accurate cost estimation. This work contributes to that fact, by providing a longitudinal case study, comparing the economic performance of the products and the accuracy of quotations before and 4 years after the implementation of a PCS in a CTO manufacturer.

3 CASE STUDY

In order to examine the propositions a case study is performed. The purpose of this case study is to illustrate the difference between cost estimation accuracy and product profitability, when using a PCS and without one. Therefore, a longitudinal case study is performed, by making similar analysis in 2009, when the company was not using a PCS, and in 2014, 4 years after the implementation of the configurator. The reason for selecting that specific period is to ensure that the PCS has been fully integrated into the business processes of the company, therefore increasing the validity of the comparison. The data for this research was gathered from company's internal databases and was verified with experts from the company.

3.1 Background

The company analysed in this case study is a Nordic company in the building industry that operates worldwide. In the year 2014 the company had around 100 employees and yearly turnover of approximately 15 million Euro. On average the company has around 50 projects per year where the average turnover per project is approximately 300.000 Euro. The company manufactures pre-made structural elements for buildings. The product portfolio consists mainly of six products; A, B, C, D, E and F. The first four products have standard product architecture that can be adjusted to the customers' needs. Products of type E denote to all the non-standardized solutions and products of type F relate to additional features or to the parts that can be added to the standard solutions.

In 2009 the process of making budgetary quotation and the accuracy of the cost estimation were analysed, which revealed the company's performance of accurate cost estimations could be improved. The analysis also revealed that the company's procedure of using Excel sheets to make the calculations of estimating the prices resulted in many errors that could be traced to human mistakes. Based on this analysis the company decided to invest 150.000 Euro to develop a PCS to improve the processes of generating budgetary quotations. The PCS used at the company is a commercial PCS, which builds on constrains propagation. In addition to that, the company also made process improvements and changes in the product assortment that aimed to increase standardisation. The implementation of the PCS also ensured that the salespersons are going to provide the customers with valid configurations from the standard product architecture.

The development of the PCS took place in the period 2009 – 2010, and in beginning of 2011 the company had developed a PCS able to handle most of the budgetary quotations. Only products of type E, which are categorized as non-standard solutions, have not been included in the system. However, due to insufficient change management, not all employees were willing to change their work procedures and therefore they still used Excel sheets to make the cost calculations for making the budgetary offers.

In this case study the impact from implementing the PCS on the company's ability to make accurate price estimations for the budgetary offers and the company's profitability will be assessed. The analyses were done both before implementing the system and for the period of its utilization over, the past 4 years (2011-2014). Thereafter the accuracy of the calculations made by using the Excel sheets and the PCS will be compared.

3.2 Analysis of the Company's Performance Before and After Implementation of Product Configuration System

In order to compare the performance before implementing the PCS (2009) and after the implementation (2011-2014), contribution margins (CM) and contribution ratio (CR) were calculated for each

project that had been carried out at the company within the timeframe of this research. Those calculations where both based on the estimations of the budgetary quotations and both the real cost and sales prices calculated after each project had been closed. CM and CR are calculated as follows [25]:

$$CM = Sales\ Price - Cost\ Price \quad (1)$$

$$CR = CM / Sales\ Price \quad (2)$$

Finally, the deviation in the CR is then calculated as actual CR minus the estimated CR.

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

If the real cost of the project is higher than the estimated cost, it will result in negative deviation of the CR. Respectively, if the real cost of the project is less than the estimated it will result in positive deviation in the CR. The data for the analysis was extracted from the company's internal database and verified with specialist at the company. The cost prices of the projects were calculated as the sum of the costs for expenses on construction site, subcontractors, materials and salaries. The projects included in the comparison are from 2009, when only the Excel sheets were used to calculate the cost, until 2014. For the period 2011-2014 the cost calculations are either done in the PCS or by using Excel sheets. In Table 1 the main results from the analysis are listed.

Table 1. Overall analysis of the PCS contribution in terms of CR before implementation (2009) and after implementation (2011-2014)

	Performance indicators			
Year	◊	□	○	◊◊
2009	-1.5%	5.4%	14.6%	25.0%
2011	-3.6%	7.7%	28.5%	25.5%
2012	-0.7%	4.9%	8.9%	27.6%
2013	-2.4%	4.9%	9.5%	28.8%
2014	-1.1%	3.9%	2.2%	28.6%

◊ Average difference in CR □ Average absolute deviation in CR ○ Percentages of projects with greater deviation than 10% ◊◊ Average CR per project

The analysis shows that the average CR has steadily increased from 25.0% in 2009 to 28.6% in 2014. However, the overall company's goal is to have projects with CR of 30%.

The deviations in the CR also show positive improvements as the average deviations have been reduced from -1.5% in 2009 to -1.1% in 2014. Regarding the absolute value of the CR, when analyzed, the deviations showed reduction from 5.4% to 3.9%. It should also be noted that the percentages of projects with greater deviation than 10% have been significantly reduced from 14.6% in 2009 to 2.2% in 2014, as the calculations of the absolute values in the CR indicate. However in 2011, which was the first year when the PCS was utilized, the deviations in the CR increased considerably. This increased in deviations can be traced to the fact that the system had not been fully tested before implementation and the users of the system were lacking training. But as the users became more experienced in using the system and errors had been 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, which is 30%.

3.2.1 Analysis of Cost Structure and Deviations

In this section the company's cost structure and the deviations in the estimated and actual values with regards to the main cost elements is analysed. The purpose of that analysis is to identify whether cost estimations have been improved after the implementation of the PCS by analysing the main cost elements. The cost elements that are included in the analysis represent the direct cost of making the product, which covers the expenses related to materials, salaries, subcontractors and for the construction site, e.g. renting machines.

In 2009 a cost analysis was performed in order to assess the economic benefit by implementing a PCS. This benefit is highly associated to the reduction of deviations in the cost estimation, as the application of a PCS would thereby improve the budgetary quotations. In Figure 1 the results from the analysis are shown for the deviation in the CM for the cost calculations of the main cost elements.

Figure 1. Deviations in cost estimations for the projects 2009 distributed between the main cost elements

The figure above shows great deviations and irregularities in the pattern, which indicate that only a few projects were realized at the same cost as calculated. This means that the salespersons have estimated significantly lower costs for the projects than the actual ones, as the deviations are mainly negative. That means that the sales persons underestimated the cost of the project. That refers to all different cost categories, as they all deviate towards the same direction (positive or negative). Based on this it can be concluded that the accuracy of the calculations for the budgetary proposals were inadequate in 2009.

In order to see whether the situation has been improved at the company since implementing the PCS, a similar analysis was repeated in 2014, three years after implementing the PCS. The results from the analysis are shown in Figure 2.

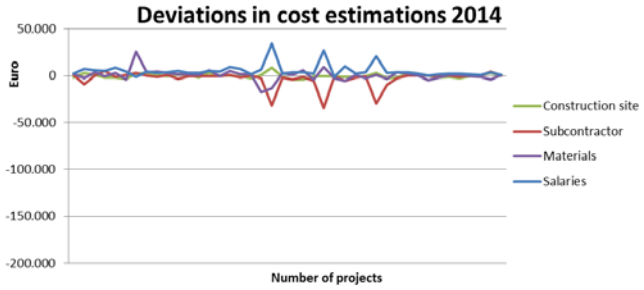

Figure 2. Deviations in cost estimations for the projects in 2014 distributed between the main cost elements

As illustrated in the above figure, when comparing the deviations in CMs of the projects from 2014, it can be clearly noted that there are far less fluctuations in the cost calculations than in 2009. Beside a few projects, the majority of them have rather low deviations from the calculated budget. By comparing the results from Figures 1 and 2, it can be realised that the accuracy of cost estimations has been improved since implementing the PCS. This is also supported by the fact that the deviations from 2009 for all the cost elements are not towards the same direction, meaning that in 2009 the deviations were negative in their overwhelming majority.

The costs in 2014 are closer to the baseline; nevertheless, three large negative spikes for the subcontractor category can clearly be seen, on the same projects with the positive spikes for the salaries. From an interview with a specialist at the company the reason for the large deviations in these three projects was due to the fact that the construction work was outsourced to subcontractors. This explains why the subcontractor category reveals large deviation and at the same time there is a positive deviation in the salary category, as the work was outsourced and therefore salaries to own employees could be reduced for the projects.

In the project where there is a large positive deviation in the material category. The explanation given was that from the time the proposal was given out and until it was finished it took several years and in the meantime a new steel structure was developed and implemented, which was much cheaper than the old structure. The large positive deviations in the cost estimations that were noticed in the 2014 analysis have therefore been reasonably explained. In the next section a more general explanation for the deviation is provided.

3.2.2 Reasons for the deviations

In order to gain a better understanding of the deviations in the cost estimations, a deeper analysis is performed, with the aim of clarifying why these deviations are still occurring at the company. The most significant deviations in the projects 2014 have been explained above, however in this section additional factors that influence the deviations will be further analysed.

The company aims to provide the customers with high quality service therefore if a customer wants to make changes to the specifications later in the process, the company will strive to adjust the solution to satisfy the customer's wishes. When such changes occur, the additional cost is added manually to the total price. This makes the actual cost of the project deviate from the initially calculated cost, but does not affect the profitability of the project.

Furthermore, the cost at the construction site is difficult to estimate since there are frequently unforeseen factors which have to be dealt with, such as difficulties to get the machines at the building side. That can result in increasing the time that the machines have to be rented and creating additional expenses due to salaries of subcontractors, which were not taken into account in the original calculation of the estimated cost. However, this threat could be reduced if technicians would examine the construction site in order to make more realistic estimations of the cost.

However, it worth mentioning that the highest peaks in the deviations of the cost calculations in 2014 are not caused by errors in the quotations, or additional costs due to unforeseen factors at the construction site but mainly because of the outsourcing work to subcontractors. Under certain circumstances, time can be limited and the company's employees might get closer to a deadline for a project and the construction team cannot finish on time. Then it might be necessary to outsource the work to subcontractors to finish on time and not delay the project, as that will also cause higher additional cost.

It can be concluded from the above analysis that the main reasons for the deviations in the cost calculations were not due to inconsistences of the PCS. Late changes from the customers, unforeseen circumstances and outsourcing are some of the main factors reported by the project managers of the company, which when occur, cause deviations in the cost calculations.

3.3 Comparison of Budgetary Proposals Made in Excel and PCS

In 2011 the PCS was first launched in the company. However, it has not been accepted by all sales representatives therefore some of them were still using Excel sheets for the calculations. The main reason for that is the lack of change management initiatives, which resulted in some employees resisting to use the PCS and therefore sticking to their old work habits. In this chapter the yearly turnover, CR of the projects and the deviations of the CR will be analysed in terms of whether they were generated by the Excel sheets or the by the PCS.

The turnover generated by projects sold through the PCS has been steadily increasing since 2011. In the year 2013 the point was reached, where slightly more proposals were generated by the use of the PCS. Figure 3 shows the yearly turnover for the proposals made in Excel and by use of the PCS.

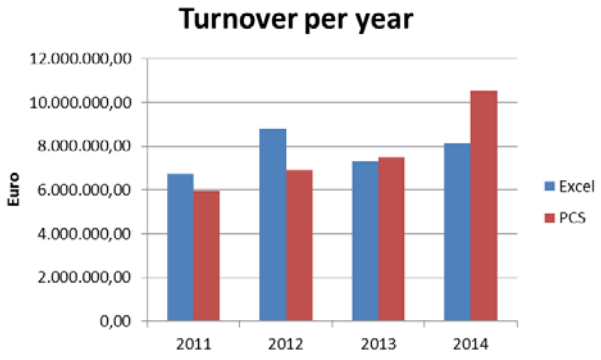

Figure 3. Comparison of turnover generated for proposals made in Excel and by use of the PCS

As can be seen from the above figure, in 2011 and 2012, the projects handled by the salespersons through the Excel sheets contributed more to the turnover of the company; even though the PCS has already been implemented in that period. This can be explained, firstly, by the reluctance that some of the salespersons showed towards including the new PCS in their working processes, as they still used Excel for the cost calculation and quotation generation. Additional, the period 2011-2012 was the initial introduction of the PCS at the company. However, the PCS did not include all products at that point of time; therefore its utilization was by definition limited. As a consequence, during the trial period the turnover contributed by the projects handled in Excel is higher than the one from the PCS, but this fact was significantly changed

in the following 2 years. So, in the period 2013-2014, when the company managed to take 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 worked out in Excel.

3.3.1 Sales Representatives and CR

The company's goal is that all projects should have a CR of 30%. An analysis of the overall performance of the company, (section 3.2) showed how the CR has been increasing since 2009. However, in order to confirm that this can be traced to the implementation of the PCS, a comparison of the CR for the budgetary proposal made by using the PCS and Excel is performed. In Figure 4, the actual CR is illustrated for the proposals made by use of the PCS and Excel.

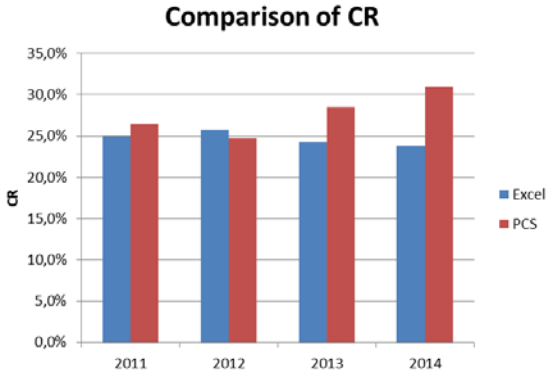

Figure 4. Comparison of CR for salespersons using Excel and PCS

From this it can be concluded that salespersons using the PCS contribute a higher CR, with an exception in the year 2012 where it was slightly lower. Furthermore, it can be seen that the gap between the CR is increasing between the salespersons using Excel and the PCS. In 2014 the average CR was 28.6%, where sale persons using the PCS had average CR 30.1% while sale persons using Excel had 23.8%. In other words, the salespersons using the PCS have managed to achieve the goal of 30%.

However as previously mentioned the products of type E, which are the non-standard products, are not included in the PCS therefore in order to make the price estimation Excel sheets are always used. Even though those products are not included in the calculations for the proposals made in Excel, when they were taken into account they only affected the CR for the proposals made in Excel by 0.2%. Therefore it can be concluded that the reason for lower CR cannot be traced to the special orders.

Another important factor is to compare the deviations in the CR between the proposals made in Excel and PCS. The results are illustrated in Figure 5.

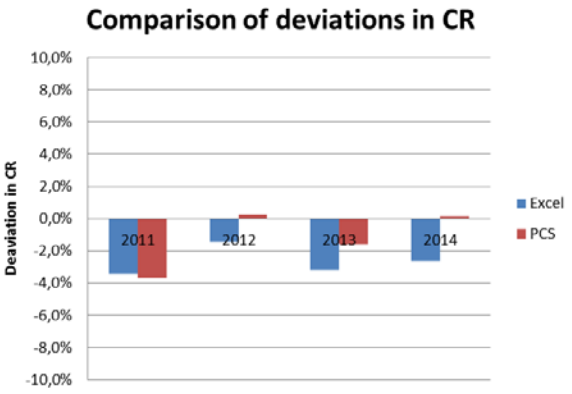

Figure 5. Comparison of deviations in CR for sale persons using Excel and PCS

As it can be seen from the above figure, the salespersons using the PCS have less deviation in their CR than the ones using Excel, with the exception of the year 2011 which was the first year the system was used in the company. Moreover, in 2012 and 2014 the deviations of the quotations made by the PCS are positive and close to 0.

The analysis of the performance of the salespersons using Excel and PCS therefore indicates that the PCS affects positively the accuracy of the cost estimation as well as the CR. Summarizing the results from this section, it can be seen that both the CR and the accuracy of estimations are improved by the utilization of the PCS. To this end, it can be concluded that the both propositions are supported by the results of the case study.

3.4 Future Initiatives

In order to improve the company's performance several factors have been identified that could reduce even further the deviations in the CR and increase the profitability of the company. The company intends to implement a check list in the end of each configuration in order to ensure that all the required information is both gathered in the sales phase and up-to-date. By implementing the check list, it is expected that errors made in the sales process will be reduced even further. Furthermore, the company is planning to enhance a higher degree of standardization in their product range, as well as move towards modular based product architecture. Finally, the company has decided to invest 140.000 Euro in further development of the PCS, in order to include more products and have greater benefits from its utilization.

4 CONCLUSIONS

The scope of this case study is to quantify the impact of implementing a PCS on product profitability and accuracy of cost estimation. The research results in significant improvements in both the CR of products sold through the PCS and the accuracy of quotations. These results confirm the propositions made in this paper. In detail, an improved performance of the margins of the products is recorded, as well as a reduction in the deviation of quotations. The comparison in the quotations' deviation is made between the same products, sold in 2009, before the company implemented the configurator, and in 2014, when the sales process

was supported by the PCS. Moreover, there is a comparison between the CR of products being sold with and without the use of the configurator for the period 2011 to 2014, when the PCS has been implemented and used to its full potential. Both comparisons lead to the same conclusion, that the contribution of the PCS is noteworthy, as the performance of the products included in the PCS is improved. Additionally, the deviations between the initial quotation provided to the customer by the PCS and the actual cost of each project are eliminated. Since the data used in the PCS is updated and all possible solutions are validated before making an offer, the quotation includes fewer errors and more accurate price estimation, when it is compared to the quotations of the products not included in the PCS.

5 DISCUSSION AND FUTURE RESEARCH

This work focuses on the benefits of implementing a PCS in a configure-to-order manufacturing company. The benefits widely discussed in the existing literature are directed towards customer satisfaction, cost reduction due to a better use of resources and elimination of errors, and improved product quality. The empirical evidence provided in this research is based on a single case study. However, the company is considered to be a typical example and highly representative in the configure-to-order industry.

This research is the first step in exploring the impact of a configurator on product's profitability. Hence, similar cases also need to be examined, in order to compare the profitability between projects going through the PCS and outside of it. By examining more cases, a deeper understanding can be gained and a more detailed explanation of the correlation between configuration tools and product profitability can be provided.

In this paper empirical evidence is provided by only one case study. Yet, the impact registered in this company indicates that there could be significant impacts from implementing a PCS, which have not been discussed in the literature previously. Therefore, this requires further research and additional case-studies in order to justify the underlying correlation between PCS and profitability increase.

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