# Complexity of Configurators Relative to Integrations and Field of Application

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*Publication date:*
2017

*Document Version*
Peer reviewed version



*Citation (APA):*
Kristjansdottir, K., Shafiee, S., Battistello, L., Hvam, L., &  Forza, C. (2017). Complexity of Configurators Relative to Integrations and Field of Application. Paper presented at 19th International Configuration Workshop, Paris, France.

# Complexity of Configurators Relative to Integrations and Field of Application

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**Abstract.** Configurators are applied widely to automate the specification processes at companies. The literature describes the industrial application of configurators supporting both sales and engineering processes, where configurators supporting the engineering processes are described more challenging. Moreover, configurators are commonly integrated to various IT systems within companies. The complexity of configurators is an important factor when it comes to performance, development and maintenance of the systems. A direct comparison of the complexity based on the different application and IT integrations is not addressed to a great extent in the literature. Thus, this paper aims to analyse the relationship of the complexity of the configurators, which is based on parameters (rules and attributes), in terms of first different applications of configurators (sales and engineering), and second integrations to other IT systems. The research method adopted in the paper is based on a survey followed with interviews where the unit of analysis is based on operating configurators within a company.

## 1 INTRODUCTION

In today's business environment customers are increasingly demanding high quality customised products, with short delivery time, and at competitive prices [1]. To respond to those increasing demands, mass customisation strategies have received increasing attention from both practitioners and researchers. Mass customisation refers to the ability to make customised products and services that fit all customers' needs through flexibility and integration at similar costs to mass-produced products [2]. Configurators are used to support design activities throughout the customisation process in which a set of components and connections are pre-defined, and constraints are used to prevent infeasible configurations [3].

Configurators can be used to support different specification process at companies, which can include sales, design/engineering and/or production. Configurators can bring substantial benefits, such as shorter lead times for generating quotations, fewer errors, increased the ability to meet customers' requirements regarding product functionality, use of fewer resources, optimised product designs, less routine work and improved on-time delivery [4–8].

Configurators used to support the engineering processes are considered more complex [1,9]. However, a direct comparison of configurators to support the different applications within the same company has not been conducted. Furthermore, in configuration projects, there is usually the need for integration to IT systems, such as ERP, CAD, PLM and PIM systems. However, the literature does not address what influences it will have on the configurators complexity when integrations to other system are made.

In this paper, the complexity of configurators is determined based on parameters, or a number of rules and attributes, included in the configurators. By analysing the complexity in terms of application, configurators supporting sales and engineering processes, and in relation to different integrations, it will give more understanding of what factors influence the complexity of the configurators. The complexity of configurators is a relevant topic as it influences the performance of the system and affects the effort needed in terms of development and maintenance. Nevertheless, complexity can be both good and bad depending on whether it is value adding or not. This paper, therefore, aims to provide more understanding of factors influencing the complexity of configurators by providing answers to the following research questions (RQs):

> ***RQ 1*:** What are the differences in terms of complexity between sales and engineering configurators?
>
> ***RQ 2*:** What are the differences in terms of complexity when configurators are integrated to other IT systems?

To answers to the RQs, a survey followed with interviews is conducted. The results presented in this paper are preliminary as this is an ongoing study. This includes analysis based on one company where the unit of analysis is based on operating configurators within the company.

The structure of the paper is as follows. Chapter 2 discusses the literature background for the study, and Chapter 3 explains the research method. Chapter 4 presents the results of the research, and Chapter 5 discusses the results in relation to the RQs and presents the conclusion.

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## 2 Literature Review

This section aims to provide the background for the study. Section 2.1 discusses configurators and integrated system and provides a definition of configurators' complexity. Section 2.2 discusses the difference between configurators supporting sales and engineering processes.

### 2.1 Configurators and Integrated Systems

The underlying IT structure of a configurator consists of configuration knowledge representation and reasoning, conflict detection and explanation, and finally a user interface [10]. Configurators can be applied as standalone software, as well as data-integrative and application-integrative systems [11]. Data-integrative configurators can be used to avoid data redundancies, and application-integrative configurators allow for communication across different applications (e.g. CAD drawings can be generated from the output of the configurator) [11]. In terms of data integration for configurators, common sources for master data can be found in Enterprise resource planning (ERP) systems that often define a production-relevant view of the material. This is required for the assembly process, product data management (PDM) and product lifecycle management (PLM) systems, which are used to maintain production relevant data. Finally, product information management (PIM) systems are used to maintain sales-relevant data [12]. Different configurators can be integrated into terms of, for example, sales and engineering configurators [13]. Finally, configurators can be integrated into suppliers systems to retrieve the required data from the configuration processes [14].

To measure the complexity of configurators, Brown et al. [15] categorize them into three major components; (1) execution complexity, (2) parameter complexity, and (3) memory complexity. Execution complexity covers the complexity involved in performing the configuration actions that make up the configuration procedure, and the memory complexity refers to the number of parameters that system manager must remember. In this paper, the parameter complexity is considered the most important, as it measures the complexity of providing configuration data to the computer system during a configuration procedure [15]. Therefore, the article focuses on parameters complexity to determine the complexity of the configurators. The parameter complexity is determined based attributes and rules included in the configurators.

### 2.2 Sales and Engineering Configurators

Configurators are used to support the product configuration process, which consists of a set of activities that involve gathering information from customers and generating the required product specifications [13,16]. The product configuration process can be divided into sales and technical configuration processes [17]. The sales configuration process is concerned with identifying products that fulfil customers' needs and determining the main characteristics of the products [17]. The technical configuration process, on the other hand, is concerned with generating documentation for the product based on the input gathered during the sales phase [17]. In this article, the technical configurations are referred to as the configurators supporting the engineering processes. Another dimension of the configuration process is production configuration [18].

The challenges of configurators used to support the engineering companies are described in terms product characteristics, customer relations, and long time span of projects [19]. Further, the sales process in engineering companies can be categorized where a high-level design is made in the sales phase, and the actual design processes do not start before the sale is confirmed. Thus, sales configurators in engineering companies are often modelled on a high level of abstraction where the engineering configurators that are concerned with the actual design of the product have to include more detailed information [4]. This usually leads to higher complexity of the configurators supporting the engineering than the sales processes.

## 3 RESEARCH METHOD

The chosen research method for this article is survey followed with interviews. As this is still ongoing study, only one company is analyzed. However, by only including one company, it was possible to get an in-depth knowledge of the configuration setup and compare the complexity of the configurators within the same settings. The unit of analysis is based on operational configurators at the company, where a configurator is defined as a system that has its own knowledge base or product model and user interface. The company uses commercial configuration software for all of their configurations. Meaning that the same modelling paradigms are used in the company for all the configurators, which is a requirement to compare the complexity of the different configurators.

The case company introduced in the study has a world-leading position in providing process plants and related equipment for industrial use. The company has utilized configurators since 1999 and has currently 159 operational configurators, which support the product specification processes both in sales and the engineering. The company, therefore, has an extensive experience from working with configurators.

To analyse the complexity of the configurators first, a questioner was developed and reviewed several times by the research team in order to check consistency and understandability. Secondly, the questionnaire was emailed to the company, and an interview was set up. Based on the first interview it was decided that the data gathering would be conducted in collaboration with one of the project manager from the configuration team for two days. The data was gathered from internals systems and evaluated by the project manager to check accuracy and consistency.

The data was then analyzed in Microsoft Excel in relation to the RQs. First, the configurators were grouped according to processes they supported, or into sales, sales and engineering, engineering and few configurators where grouped under others. A limitation of the data is that the majority of the configurators are used to support the engineering processes (75%), and sales and engineering processes (19%) while there are few configurators used to support only sales processes (3%) and finally configurators used to support other processes are (2%). Nevertheless, the results presented are thought to provide valuable insight into the parameters complexity of configurators, while further data gathering is planned to support the findings. Secondly, the data related to the configurators integrated IT systems were grouped. In cases where there is more than one integration to the configurators they were listed under a combination of integrations, which included the following combinations: (1) CAD and ERP, (2) CAD, ERP and calculation systems, and finally (3) ERP and calculation system. This is required as the focus of the study is to analyze integrations to what IT systems result in the most complexity and therefore including combinations of integrations would give biased results.

## 4 RESULTS

In this chapter, the main result of the survey are presented aligned with the two RQs introduce in the paper.

Section 4.1 elaborates on the complexity of the configurators used in the sales, both in sales and engineering processes and finally only in the engineering processes (RQ 1). Section 4.2 elaborates and the complexity of the configurators in relation to integrations to IT systems (RQ 2). The integrations include ERP, CAD, calculation systems, integrations to other systems or combination of systems and finally few configurators that have no integrations. The results presented are based on data from 159 configurators that are used within on company as explained in Section 3.

### 4.1 Complexity in Relation to Engineering and Sales Configurators

This section provides the results in relation to the complexity based on sales and engineering configurators. Figure 1 shows the percentages of configurators used to support the (1) sales, (2) sales and engineering, (3) engineering, and finally (4) other activities.

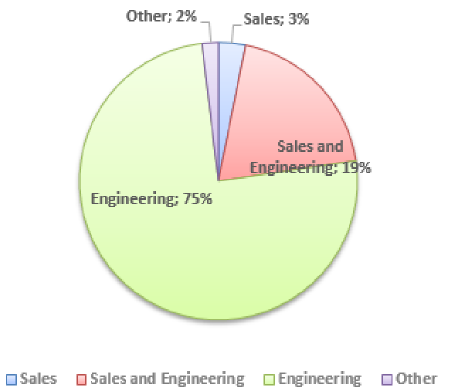


**Figure 1.** Percentages of configurators used to support different activities at the company.

As can be seen in Figure 1 only 5% of the total configurators support the sales processes, while 19% of the configurators are used to support both sales and engineering, 75% of the configurators are used to support only engineering, and 2% support other activities.

The complexity of the configurators used for the different activities is shown in Figure 2 in terms of average numbers of rules and attributes and total where the numbers of rules and attributes are summarized.

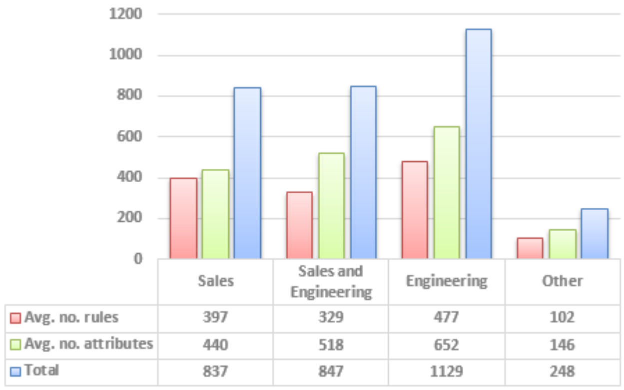


**Figure 2.** The complexity of the configurators used to support the different activities at the company.

Figure 2 shows that in terms of rules configurators used by engineering have on average 477, while sales have 397 and configurators used by sales and engineering have on average 329. In terms of attributes, configurators used by engineering have on average the most attributes or 652, while configurators used by sales and engineering have on average 518 and sales have 440. Finally, as previously defined, the complexity of the configurators is determined based on parameters or the sum of attributes and rules. Thus, configurators supporting only engineering activities have the highest total score of complexity or 1129 while if we look at the configurators only supporting sales or sales and engineering the total score is 837 and 847 respectively. Other configurators supporting simpler tasks at the company have the lowest rate of complexity or only 248.

### 4.2 Complexity of Configurators in Relation to Integrations

In the company used for this study, the application of the configurators was divided according to the integrations. The integrations included the following IT systems (1) ERP, (2) CAD, (3) calculation systems, (4) combination of the above-mentioned systems, and in few case (5) other systems. Only 4% of the configurators did not have any integration, while 70% of the configurators were integrated into one of the above-mentioned systems and 26% were integrated to one or more of the systems. Figure 3 shows the percentages of integrations the different configurators have.

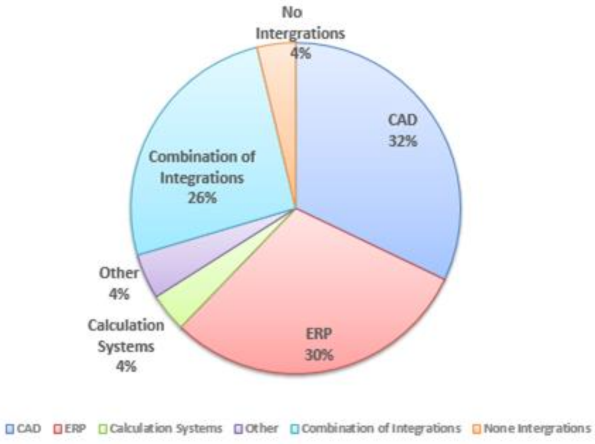


**Figure 3.** Percentages of integrations and combinations of integrations to different IT systems used at the company.

As can be seen in Figure 3 the majority of the configurators are intergraded to the CAD and the ERP system used at the company or 32% and 30% respectively while only 4% are integrated only to calculation systems or other IT systems used at the company. Finally, 26% of the configurators are integrated to more than one of the above mentioned IT systems.

The complexity of the configurators integrated to the different IT systems is shown in Figure 4 in terms of average numbers of rules, attributes and then the sum of the average rules and attributes.

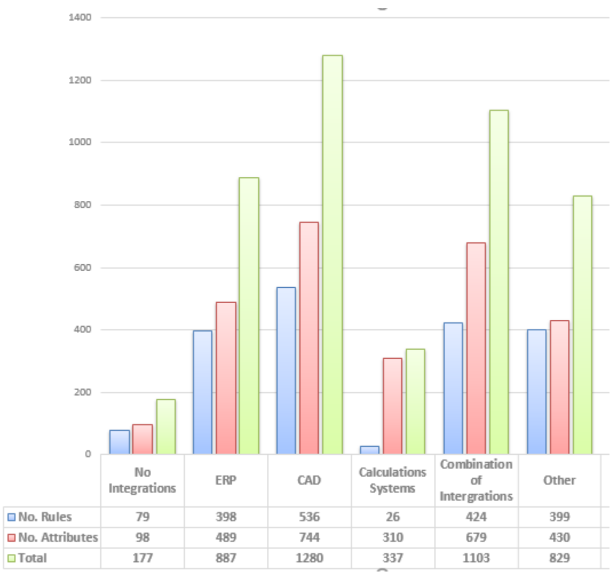


**Figure 4.** The main characteristics of the configurators integrated to different IT systems at the company.

From Figure 4 it can be seen that in terms of both attributes and rules the configurators integrated to CAD system score the highest in terms of complexity. Configurators that have combinations of integrations, or more than one integration, have the second highest score. That can be explained by the fact that in most cases that also includes integration to a CAD system. By looking into configurators that have integrations to calculation systems it can be seen that they have the fewest rules, may be due to the calculations being performed within another system. Finally, it can be seen that configurators with no integration have the lowest complexity factor.

## 5 DISCUSSIONS AND CONCLUSIONS

This study provides insights into the complexity of the configurator where the complexity is analysed based on parameters, which consists of numbers of attributes and rules. The complexity is analysed first based on the field of application (sales and engineering) and then based on integrations to different IT systems. The results provided in the present article aim to contribute to the field of configurators' complexity and the factors influencing them. This is an important topic not only for the research community but also for practitioners. The results show that a difference can be found in relation to the complexity by analysing the field of application and different kind of integrations.

The first research question in this study aims to identify if there is any relationship between the complexity of the configurators and the field of applications. Our analysis shows that the configurators that are only aimed at supporting the engineering processes have the highest parameters complexity. However, there was only a slight difference between the complexity factor of the configurators only used to support sales and the configurators used to support both sales and engineering.

The second research question aims to analyse the relationship between integrations and complexity of the configurators. In the literature, it is discussed how configurators are integrated to different IT systems, e.g., [11–14,18]. However, the literature does not explain to what extent the integrations to different IT system will influence the complexity level of the configurators. In this paper integration to CAD, ERP and calculation systems are analyzed. The result shows out of the above mention IT systems the complexity of the configurators integrated to CAD systems is the highest. This can be supported by the fact that in order to generate CAD files from the configurators, they have to be able to support the detail design including all the product dimensions, which will increase the complexity. Thus, configurators integrated to CAD systems can be defined as product design configurators, which support the engineering processes where the complexity can be anticipated to be higher even though not integrated into a CAD system. Configurators integrated to ERP systems scored as the second highest while configurators integrated to calculation systems scored the lowest out of those systems. When configurators are integrated to calculation a system, the reason is usually that the calculations being too complex or specialized to handle within the configurator. This supports the fact that configurators integrated to calculations systems have very low number of rules and thereby they also have low parameters complexity.

The result presented in the paper is based on answers and interviews from one company. This is thought to provide valuable insight as by studying one company an in-depth knowledge about the configuration setup could be accessed. Furthermore, it allows comparison of the complexity as all the configurators are developed based on the same commercial configuration platform. More companies will be contacted in the future, to enable cross-functional comparison.

## REFERENCES


[1] L. Hvam, J. Riis, N.H. Mortensen, Product customization, Springer, Berlin Heidelberg, 2008.

[2] B.J. Pine II, B. Victor, Boyton, ‘Making mass customization work’, *Harvard business review,* **71,** 109–119, (1993).

[3] A. Felfernig, G.E. Friedrich, D. Jannach, ‘UML as domain specific language for the construction of knowledge-based configuration systems’, International Journal of Software Engineering and Knowledge Engineering, **10**, 449–469, (2000).

[4] A. Haug, L. Hvam, N.H. Mortensen, ‘The impact of product configurators on lead times in engineering-oriented companies’, *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, **25**, 197–206, (2011).

[5] L. Hvam, A. Haug, N.H. Mortensen, C. Thuesen, ‘Observed benefits from product configuration systems’, *International Journal of Industrial Engineering-Theory Applications and Practice*, **20**¸ 329-338, (2013).

[6] A. Trentin, E. Perin, C. Forza, ‘Product configurator impact on product quality’, *International Journal of Production Economics*, **135**, 850–859 (2012).

[7] L.L. Zhang, ‘Product configuration: a review of the state-of-the-art and future research’, *International Journal of Production Research*, **52**, 6381-6398, (2014)

[8] A. Trentin, E. Perin and C. Forza, ‘Overcoming the customization-responsiveness squeeze by using product configurators: Beyond anecdotal evidence’, *Computers in Industry*, **62**, 260-268, (2011).

[9] S. Shafiee, L. Hvam, A. Haug, M. Dam, K. Kristjansdottir, ‘The documentation of product configuration systems: A framework and an IT solution’ *Advanced Engineering Informatics*, **32**, 163–175, (2017).

[10] A. Felfernig, L. Hotz, C. Bagley, J. Tiihonen, Knowledge-based configuration: From research to business cases, Morgan Kaufman, 2014.

[11] T. Blecker, N. Abdelkafi, G. Kreutler, G. Friedrich, ‘Product configuration systems: state of the art, conceptualization and extensions, (2004).

[12] T. Krebs, ’Encoway’, in: A. Felfernig, L. Hotz, C. Bagley, J. Tihonen (Eds.), Knowledge-Based Config. From Research to Bussiness Cases, Morgan Kaufman, pp. 271–279, 2014.

[13] C. Forza, F. Salvador, Product information management for mass customization, Palgrave Macmillan, New York, 2007.

[14] L. Ardissono, A. Felfernig, G. Friedrich, A. Goy, D. Jannach, G. Petrone, R. Schafer, M. Zanker, ’A Framework for the Development of Personalized, Distributed Web-Based Configuration Systems’, *AI Magazine*, **24,** 93, (2003).

[15] A.B. Brown, A. Keller, J.L. Hellerstein, ’A Model of Configuration Complexity and its Application to a Change Management System’ *Integrated Network Management, 2005. IM 2005. 2005 9th IFIP/IEEE International Symposium on*, **4**, 13-27, (2007).

[16] C. Forza, F. Salvador, ’Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems’, *International journal of production economics*, **76**, 87-98, (2002).

[17] C. Forza, F. Salvador, ’Application support to product variety management’, *International Journal of Production Research*, **46**, 817-836, (2008)**.**

[18] L.L. Zhang, E. Vareilles, M. Aldanondo, ’Generic bill of functions, materials, and operations for SAP2 configuration’, *International Journal of Production Research*, **51**, 465-478, (2013)..

[19] T. D. Petersen, “Product Configuration in ETO Companies,” in Mass Customization Information Systems in Bussines, T. Blecker, Ed. Igi Global, 2007, ch. 3, pp. 59 – 76.