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INTEGRATING BUSINESS PROCESS SOFTWARE IN MASS CUSTOMIZATION

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Abstract: *The 'mass' component of mass customization commits companies to deliver according to the customer's individual expectations as efficient as possible, in terms of e.g. cost and delivery time. This entails that all information required to generate, fulfill and deliver the customer order is exchanged rapidly, without errors, between business functions at the mass customizer. Usually, this information is stored in a range of software fit for different business process purposes. These systems should be tightly integrated to secure an efficient order process. Many companies still struggle with disintegrated software solutions that require substantial manual transfer of data between systems. This paper presents insights into the status and needs for business process software integration in mass customization.*

Key Words: ***Mass Customization, Order Management, Information Handling, System Integration***

1. INTRODUCTION

The generation and processing of orders in mass customization can be divided into four steps: (1) building the product catalog; (2) configuring customer orders; (3) transferring orders to manufacturing, and; (4) manufacturing customized orders [1]. Information technology plays an ever more important role in executing these steps. It provides the means to integrate customers in co-designing, product specification and product configuration [2], as well as enabling orders to be fulfilled correctly through the integration of information flows [3].

In an ideal world, the order elicitation stage of a typical mass customization order process could involve a customer specifying his or her product in a company's product configuration system [4]. Prices are updated automatically as the customer makes alterations to the product, and the delivery date of the product is displayed with certainty as the customer hits the 'purchase' button. All relevant customer and order information is automatically registered in the company's customer relationship management (CRM) and enterprise resource planning (ERP) systems, and a production order is automatically released to the shop floor, where a manufacturing execution system (MES) schedules and executes the production of the order. Upon production completion, the order status is updated in the ERP system. At the same time, consignment notes are printed, and a request for pickup is automatically sent to the logistics provider. The customer simultaneously receives a notification, stating that the product is completed and will be delivered at the agreed time and place.

In reality, the process can be far more cumbersome. Resellers with proprietary systems may be involved in the choice navigation, and many operations in the order management process involve time-consuming manual registration and distribution of information. Typically, there is substantial communication involved to define right product solutions and delivery dates, which is carried out over e-mail and telephone. Often, this information needs to be registered manually in various freestanding systems, to calculate the correct price and offer an accurate delivery date to the dealer or reseller, which communicates this to the end customer. The production planning may also involve a lot of manual registration and transfer of information between different systems. After sales/marketing have checked capacity and registered the order in the ERP system, many companies generate rough production plans based on the registered orders. However, often these rough plans cannot be used directly in production. Instead, the plans are adjusted, often manually, due to e.g. change orders, failed credit checks, overbooking, levelling of production and product dependent bottlenecks that are not taken care of automatically by the systems. Thereafter, these adjusted plans are transferred to production. During production there is little registration of progress, which makes it hard both to communicate actual progress and capacity to the front-end, and update orders that have been released to production. The customer may receive little or no status updates until he or she receives the ordered goods.

Much of the difference between the two customer journeys above can be ascribed to a lack of integration of front-end (e.g. customer choice navigation processes, product configuration and customer relationship management) and back-end (e.g. order management, purchasing and production planning and control) business process software in the latter journey. While it is obviously inferior to the first, many companies still utilize numerous freestanding systems in their operations [5]. As noted by [6], the relative newness, complexity and mutual interdependencies among many systems ultimately add to the risks of software selection, leading

companies to make inconsistent choices or to implement the wrong systems. It is inefficient and may, at worst, induce errors in order specifications that propagate to the end customers. Resolving this issue should be a key priority for mass customizers. It is particularly important with the advent of web-based configurators as a sole method for customer involvement, as improved order acquisition and product fulfillment support systems are needed to fully reap the benefits of such tools [7,8] – such as reduced quotation lead-time, fewer errors and increased customer satisfaction as their expectations are better met [8-12].

Integration comes with a cost, and is often a question of priority. The purpose of this paper is to gain greater insight into this challenge of priority that many mass customizers are facing. More specifically, the paper provides insights into three mass customizers' status quo and perceived importance of integrating their business process software. The remainder of the paper is structured as follows. First, the research method is described. This includes an introduction to the three case companies, as well as the evaluation scheme used to assess the case companies' anticipated and current business process software integration. Thereafter, the evaluation results are presented. These are followed by a discussion. Finally, the paper is concluded.

2. RESEARCH METHOD

The empirical data have been collected through a case study of three Norwegian companies that have worked actively with mass customization over several years; lately through the joint research project *Custom^R*, funded by the Research Council of Norway. All three companies are currently working on developing web-based configurators as part of the research project, with focus on front-end and back-end integration. As part of the research, the companies were asked to state their current level of integration of different types of business process software, as well as their anticipated integration needs in times to come.

2.1 Integration Evaluation Scheme

To evaluate the perceived importance of business process software integration, a closeness rating analysis scheme has been applied. More specifically, the case companies were asked to evaluate the required interdependence of a set of business process software categories. The categories, which were constructed after an initial mapping of the companies' current software, were:

1. Enterprise resource planning (ERP)
2. Manufacturing execution system (MES)
3. Order/customer relationship mngt. (CRM)
4. Machine software
5. Webpage
6. Payment system (credit, payment, invoicing)
7. Internal product database (PLM/PDM)
8. External product database (e.g. BIM)
9. Computer aided design (CAD)
10. Visual management (incl. Business Intelligence)
11. Customer/supplier portal (incl. EDI)
12. Consignment/transportation portal
13. HSE system
14. Marketing (incl. Social media and newsletters)
15. Office system (typically Microsoft office)
16. Configurator

To evaluate the companies' perceived importance of integration, the interdependence between the categories was measured using the following scale: Absolutely necessary (A); essentially important (E); important (I); ordinary closeness (O); unimportant (U); undesirable (X). To assess the current integration, a similar scheme was used, with three categories: Fully integrated (I); partly integrated (O) and not integrated (*).

The companies were responsible for finding the person(s) most fit for carrying out the evaluation within their operations. For Company A, B and C, this was primarily the IT manager, the factory and finance managers, and the manager of IT and administration, respectively. The difference in respondents can be explained by differences between the case companies, as shown in the next subsection.

2.2 Case Companies

The three case companies differ in terms of design, marketing, sales, modularization, manufacturing, distribution etc. Over the last years, their improvement efforts have had varying focus and starting points, and their mass customization maturity varies. However, they all share the need to integrate and visualize front- and back-end operations to a larger degree. Table 1 summarizes some of their characteristics and past and future improvement efforts.

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Table 1. *Overview of companies*

Company	A	B	C
Founded	1996	2002	2008
No. employees	76	37	30
Turnover '16	82 528' NOK	124 737' NOK	32 549' NOK
Products	Doors and windows	Kitchen ventilators	Waste handling & cleaning
Solution space	"Infinite" (only limited by physical size)	Thousands (full NCS/RAL color range)	Thousands (full NCS/ RAL color range)
Demand and production characteristics	Mostly make-to-order, some make-to-stock due to seasons, batch production for large orders, otherwise one-piece flow	Make-to-order, one-piece flow	Mix of make-to-order (projects) and make-to-stock (predictable demand), mostly batch production
Product variety determinants	Glass, insulation degree, shape, size, crossbars and posts, opening possibilities, hinges and fittings, sealing and colors	Model type, material, size, color	Model type, color/ design
Main improvement focuses in the last years	Reduction of delivery times, process improvement	Production process improvement and automation	Production planning and control, automation
Main challenge/ future focus	Visualization of goods and info. flows, visual tools that keep employees updated about production progress and priorities	Solution space development, choice navigation, visualization of goods and info. flows, integration of customer and production orders	Visualization of goods and info. flows, materials handling, choice navigation, product smartness

3. EVALUATION RESULTS

This section presents the evaluation results. The first subsection shows the companies' perceived importance of integration (Fig. 1-3), while the second shows the current integration status (Fig 4-6).

3.1 Perceived Importance of Integration

Company A – Doors and windows

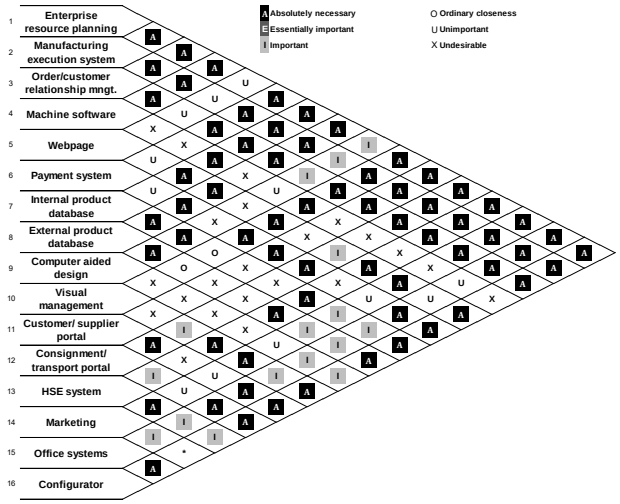

Fig. 1. *A's perceived importance of integration*

Company B – Kitchen ventilators

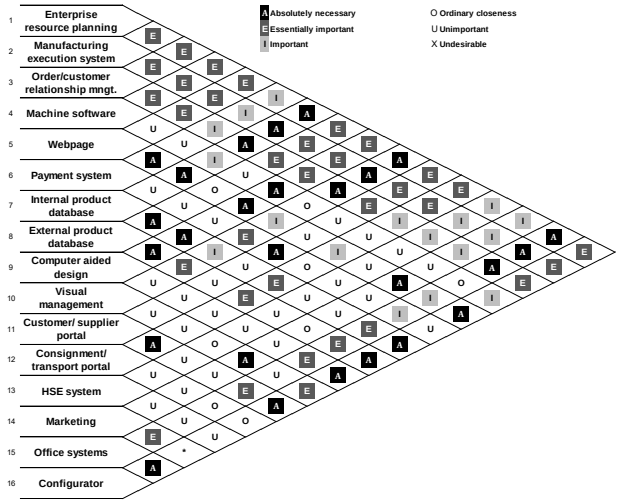

Fig. 2. *B's perceived importance of integration*

Company C – Waste handling and cleaning

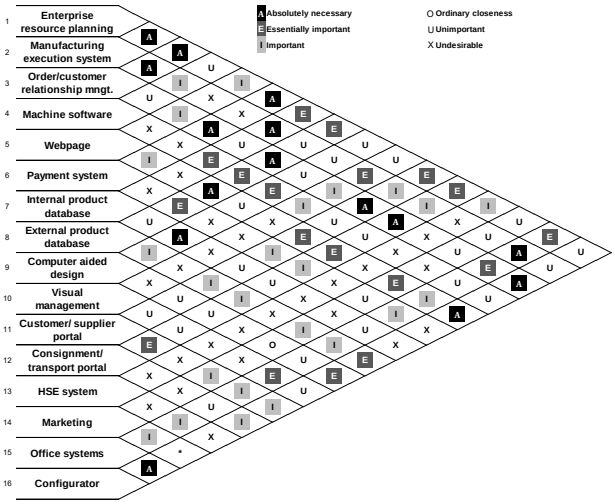

Fig. 3. *C's perceived importance of integration*

3.2 Current Integration Status

Company A – Doors and windows

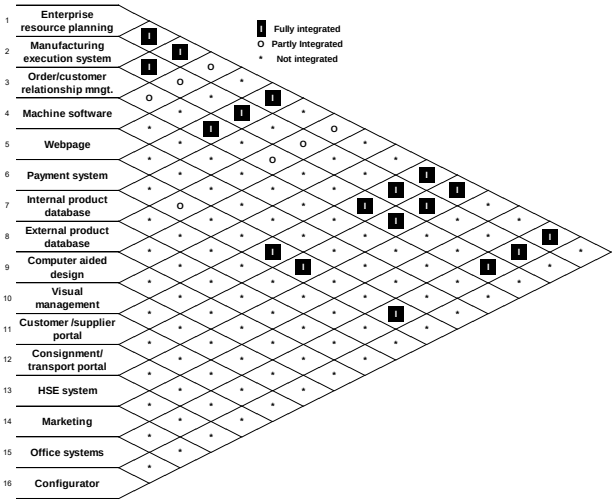

Fig. 4. *A's current integration status*

Company B – Kitchen ventilators

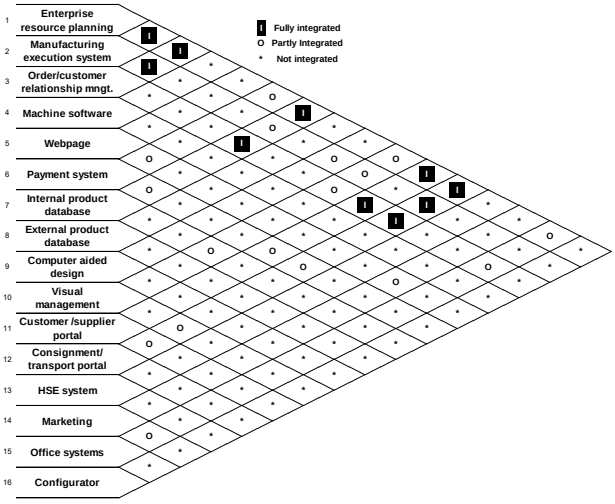

Fig. 5. *B's current integration status*

Company C – Waste handling and cleaning

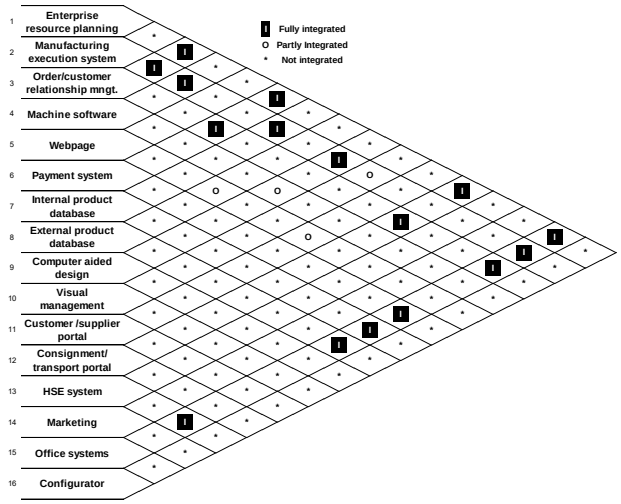

Fig. 6. *C's current integration status*

4. DISCUSSION

4.1 Importance of Integration

At first sight, the companies differ quite a lot with respect to the relative importance of integrating different business process software (Fig. 1-3). For instance, Company A sees it as 'absolutely necessary' (A) to integrate a substantial amount of systems, while the number of As in Company C's evaluation is scarce. Further, Company A does not use the 'essentially important' (E) category, whereas Company B has a substantial number of Es. Numerous such comparisons can be made based on the charts. To get an overview, it can be useful to look at how the business process software categories rank.

Company A – Doors and windows

Table 2 shows the frequency of different integration importance categories (A, E, I, O, U, X) for each business process software, as evaluated by Company A. The last column shows a ranking based on the number of 'absolutely necessary' (A) for each software category in the evaluation. As is evident, ERP, MES and CRM rank at first place (13A). Configurator follows on second place (12A), while internal and external product databases, payment and visual management systems are on third place (9A). On the opposite, machine software has the highest number of 'undesirable' (8X), followed by customer/supplier portal (7X) and computer aided design (6X), respectively.

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Table 2. A's business process software ranks

Business process software	**A**	**E**	**I**	**O**	**U**	**X**	**#**
Enterprise resource planning (ERP)	13	0	1	0	1	0	**1**
Manufacturing execution system (MES)	13	0	1	0	1	0	**1**
Order/customer relationship mngt. (CRM)	13	0	1	0	1	0	**1**
Machine software	5	0	0	0	2	8	**7**
Webpage	6	0	1	0	5	3	**6**
Payment system (credit, payment, invoicing)	9	0	0	0	3	3	**3**
Internal product database (PLM/PDM)	9	0	2	1	1	2	**3**
External product database (e.g. BIM)	9	0	2	1	0	3	**3**
Computer aided design (CAD)	2	0	5	0	2	6	**8**
Visual management (incl. Business Intelligence)	9	0	2	2	0	2	**3**
Customer/ supplier portal (incl. EDI)	7	0	0	0	1	7	**5**
Consignment/ transportation portal	7	0	3	0	1	4	**5**
HSE system	8	0	3	0	0	4	**4**
Marketing (incl. Social media and newsletters)	7	0	3	0	4	1	**5**
Office system (typically Microsoft office)	7	0	6	0	2	0	**5**
Configurator	12	0	2	0	0	1	**2**

Company B – Kitchen ventilators

Table 3 shows the frequency of different integration importance categories, as evaluated by Company B. As in Table 2, the last column shows a ranking based on the number of 'absolutely necessary' (A) for each software category in the evaluation. For Company B, the internal product database and configurator rank at first place (7A), while the webpage and computer aided design follows in second place (5A). Visual management and office system rank third place (4A). It should be mentioned that the company uses the 'essentially necessary' (E) category quite frequently, and that the ERP, MES and CRM could arguably rank in first place when also including this category. Company B does not use the 'undesirable' (X) category. However, when considering the 'unimportant' (U), the least important systems to integrate are HSE (11U), customer/supplier portal (8U) and machine software, payment and marketing (7U).

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Table 3. B's business process software ranks

Business process software	**A**	**E**	**I**	**O**	**U**	**X**	**#**
Enterprise resource planning (ERP)	3	9	3	0	0	0	**5**
Manufacturing execution system (MES)	3	9	3	0	0	0	**4**
Order/customer relationship mngt. (CRM)	3	8	4	0	0	0	**4**
Machine software	1	3	2	2	7	0	**6**
Webpage	5	3	3	1	3	0	**2**
Payment system (credit, payment, invoicing)	2	1	4	1	7	0	**5**
Internal product database (PLM/PDM)	7	2	2	0	4	0	**1**
External product database (e.g. BIM)	3	6	0	2	4	0	**4**
Computer aided design (CAD)	5	4	0	0	6	0	**2**
Visual management (incl. Business Intelligence)	4	3	2	2	4	0	**3**
Customer/ supplier portal (incl. EDI)	3	4	0	0	8	0	**4**
Consignment/ transportation portal	1	4	2	3	5	0	**6**
HSE system	0	0	3	1	11	0	**7**
Marketing (incl. Social media and newsletters)	3	1	3	1	7	0	**4**
Office system (typically Microsoft office)	4	5	2	2	2	0	**3**
Configurator	7	4	1	1	2	0	**1**

Company C – Waste handling and cleaning

Table 4 shows the frequency of different integration importance categories, as evaluated by Company C. As in Table 2 and 3, the last column shows a ranking based on the number of 'absolutely necessary' (A) for each software category in the evaluation. Company C ranks CRM in the first place (7A), MES in the second (4A) and ERP and configurator on third place (3A). HSE is by far the system deemed most undesirable to integrate with other systems (13X), followed by payment system and visual management (7X) and internal product database (6X).

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Table 4. C's business process software ranks

Business process software	**A**	**E**	**I**	**O**	**U**	**X**	**#**
Enterprise resource planning (ERP)	3	5	2	0	5	0	**3**
Manufacturing execution system (MES)	4	1	3	0	4	3	**2**
Order/customer relationship mngt. (CRM)	7	1	2	0	4	1	**1**
Machine software	0	3	2	0	6	4	**7**
Webpage	2	3	4	0	1	5	**4**
Payment system (credit, payment, invoicing)	2	1	4	0	1	7	**4**
Internal product database (PLM/PDM)	2	2	0	0	5	6	**4**
External product database (e.g. BIM)	2	4	5	0	2	2	**4**
Computer aided design (CAD)	1	2	1	1	7	3	**5**

Visual management (incl. Business Intelligence)	0	2	2	0	4	7	**6**
Customer/ supplier portal (incl. EDI)	1	3	6	0	4	1	**5**
Consignment/ transportation portal	1	3	4	0	5	2	**5**
HSE system	0	0	2	0	0	13	**6**
Marketing (incl. Social media and newsletters)	0	2	3	1	4	5	**6**
Office system (typically Microsoft office)	2	3	6	0	4	0	**4**
Configurator	3	3	2	0	4	3	**3**

It is evident from the results that all three companies regard integration of ERP, MES, CRM and configurator as important. HSE system is ranked the least important to integrate by two companies (B and C), while customer/supplier portal is regarded second least important for two companies (A and B) Other than that, there are quite a few differences. For instance, integration of CAD is ranked second most important in Company B, while it is ranked third last in Company A. Similarly, the internal product database is regarded most important to integrate in Company B, and third last in Company C. The top and bottom three ranks are summarized in Table 5.

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Table 5. Top and bottom three ranks

#	Company A	Company B	Company C
1	Enterprise resource planning (ERP) Manufacturing execution system (MES) Order/customer relationship mngt. (CRM)	Internal product database (PLM/PDM) Configurator	Order/customer relationship mngt. (CRM)
2	Configurator	Webpage Computer aided design (CAD)	Manufacturing execution system (MES)
3	Internal product database (PLM/PDM) External product database (e.g. BIM)	Visual management Office system	Enterprise resource planning (ERP) Configurator
...			
14	Computer aided design (CAD)	Machine software Payment system (credit, payment, invoicing)	Internal product database (PLM/PDM)
15	Customer/ supplier portal (incl. EDI)	Customer/ supplier portal (incl. EDI)	Payment system (credit, payment, invoicing) Visual Management
16	Machine software	HSE system	HSE system

4.2 Integration Status

While all companies see business process software integration as important, the current integration status is relatively scarce. As is evident from Fig. 4-6, most systems are not integrated (*), while a few are either fully (I) or partly (O) integrated. Having 16 system categories, we have 120 different integration points. When considering Table 2, 3 and 4, and consider categories A-O as integrations that should be made (omitting the priority), we find that Company A, B and C render important 86, 85 and 59 integration points, respectively. As of now, the number of full integration points for the three companies are 18, 16 and 16, respectively. Partial integrations count 7, 4 and 4. This is illustrated in Fig. 7 below.

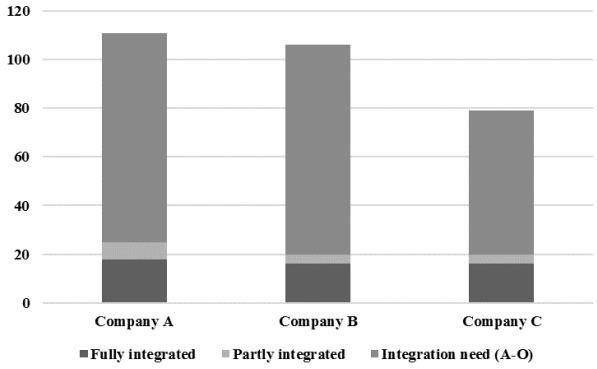

Fig. 7. *Comparison of integration status.*

For the most part, the fully integrated systems are deemed absolutely (A) or essentially (E) important by the companies. However, there are some exceptions. For instance, Company C has fully integrated their internal product database and office system, even though they deem this integration unnecessary (U). This may be a result of unconscious integration processes in the past. Bearing in mind that integration comes with a cost, companies should avoid unnecessary system integration, and instead prioritize absolutely necessary interaction points.

5. CONCLUSION

The purpose of this paper has been to gain greater insight into the challenge of business process software integration customizers are facing. More specifically, the paper has provided insights into three mass customizers' status quo and perceived importance of integrating their business process software. These systems should be tightly integrated to secure an efficient order process. However, as is evident from the case study, companies still struggle with disintegrated software solutions. This leads to substantial manual transfer of data between systems.

While the paper is a first step towards building a greater understanding of business process software integration in mass customization, there are several limitations that may be addressed in future work. For instance, the ranking system used to evaluate perceived importance of different integration points may have been understood differently by the case companies. There is a lack of numerical values guiding the evaluation scheme, and the evaluation of integration importance relies heavily on gut feeling. The same applies for the evaluation of current integration status, where the companies are asked to state whether systems are fully or partly integrated. Further, the business process software categories may be refined. Some are very to the point (e.g. Configurator), while others include a wide range of functionality (e.g. office system). Future work could also include more case companies, to better understand the relationship between company characteristics and integration status and needs. At this point, it is hard to draw conclusions on this matter. Finally, the study finds that there is a substantial gap between what companies see as necessary levels of business process software integration, and their current integration status.

6. REFERENCES

[1] G. Da Silveira, D. Borenstein, and F. S. Fogliatto, "Mass customization: Literature review and research directions". *International journal of production economics*, vol. 72, no. 1, pp. 1-13, 2001.

[2] F. T. Piller, K. Moeslein, and C. M. Stotko, "Does mass customization pay? An economic approach to evaluate customer integration". *Production planning & control*, vol. 15, no. 4, pp. 435-444, 2004.

[3] F. S. Fogliatto, G. J. Da Silveira, and D. Borenstein, "The mass customization decade: An updated review of the literature". *International journal of production economics*, vol. 138, no. 1, pp. 14-25, 2012.

[4] L. Hvam, N. H. Mortensen, and J. Riis, *Product customization*. Springer Science & Business Media, 2008.

[5] C. Forza, and F. Salvador, *Product information management for mass customization*. New York: Palgrave Macmillan, 2007.

[6] C. Forza, and F. Salvador, "Application support to product variety management". *International Journal of Production Research*, vol. 46, no. 3, pp. 817-836, 2008.

[7] F. Salvador, and C. Forza, "Configuring products to address the customization-responsiveness squeeze: A survey of management issues and opportunities". *International journal of production economics*, vol. 91, no. 3, pp. 273-291, 2004.

[8] S. Shafiee, K. Kristjansdottir, and L. Hvam, "Automatic Identification of Similarities Across Products to Improve the Configuration Process in ETO Companies". *International Journal of Industrial Engineering and Management*, vol. 8, no. 3, pp. 167-176, 2017.

[9] A. Trentin, E. Perin, and C. Forza, "Product configurator impact on product quality". *International journal of production economics*, vol. 135, no. 2, pp. 850-859, 2012.

[10] A. Haug, L. Hvam, and N. H. Mortensen, "The impact of product configurators on lead times in engineering-oriented companies". *AI EDAM*, vol. 25, no. 2, pp. 197-206, 2011.

[11] L. Hvam, A. Haug, N. H. Mortensen, and C. Thuesen, "Observed benefits from product configuration systems". *International Journal of Industrial Engineering-Theory Applications and Practice*, vol. 20, no. 5/6, pp. 329-338, 2013.

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

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