Concurrent engineering: The drawbacks of applying a one-size-fits-all approach

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Abstract

The paper explores drawbacks of applying a "one-size-fits-all" approach when conducting concurrent engineering (CE). By combining the funnel analogy with considerations in terms of prioritising different requirements, the intention with our empirical study is to contribute to the prevalent understanding of managing the CE activities. The research mainly addresses CE activities at the architecture level. Two cases, each consisting of three embedded cases, present six CE projects. Each CE project involves a company located in a high-wage area and one of two captured manufacturing facilities; one is located in Eastern Europe, while the other is located in the Far East. Two projects are accomplished without significant drawbacks and only minor iterations occur. Significant drawbacks and major iterations occur in three projects; the involved companies are incapable of understanding the consequences of using "the standard integral product architecture" prior to starting up the manufacturing. Final, one project is terminated; mainly due to the applied product architecture turns up as being unusable to offer customization options, and partly due to the manufacturing- and supply chain architecture not being considered up front the development.

Keywords:
Concurrent engineering, managerial approach, one-size-fits-all, level of customisation, architecture.

Introduction

The ongoing offshoring and outsourcing result in a geographical dispersion of the concurrent engineering (CE) activities, which complicates the managerial approach. To manage the CE activities researchers draw on the funnel analogy and suggest the application of a stage/gate approach, (e.g. Ulrich and Eppinger 2016), an integrated product-industrial V-model (Sanders and Klein 2012), lean design, (e.g. Dombrowski et al. 2014) or set based CE (e.g. Belay et al. 2014). However, according to Mottonen et al. (2009) the practical realities illustrate that it is a managerial challenge for companies to prioritise the different requirements, which often are conflicting. To handle this prioritisation issue researchers either highlight the role of the architecture of the product (Fixson 2005), manufacturing aspects (Zengin and Ada 2010) or supply chain considerations (Daaboul et al. 2016).

The above valuable contributions have in common a "one-size-fits-all" approach and in this regard, it is common knowledge that Cooper (2008) has problematised a "one-size-fits-all" stage/gate approach. However, to the best of our knowledge this "one-size-fits-all" approach have not been studied in relation to CE in a globalised development set-up, where manufacturing facilities are offshored to low-wage areas.

Hence, the purpose of this research is to empirically study the drawbacks of applying the "one-size-fits-all" approach and use this understanding to suggest a method to overcome the identified drawbacks. The research question guiding this research gradually emerges *"to what extent, if any, does the "one-size-fits-all" approach influence CE"*.

The theoretical conceptualisation combines the funnel analogy with considerations related to the prioritisation among different requirements and the paper does mainly address CE at the architecture level. CE entails a gradual and coordinated creation of the product, manufacturing and supply chain. The creation of product, manufacturing and supply chain is understood as the drawing up of artefacts (Mathiasen and Koch 2015) as for instance sketches, drawings, diagrams, documentations and physical prototypes.

The empirical settings for this research consist of a company located in a high-wage area (designated OEM) and two captured manufacturing facilities, one in Eastern Europe (designated Manufacturing-Europe) and one in the Far East (designated Manufacturing-East). OEM is responsible for clarifying functional features and drawing up the concept, after which one of the two manufacturing facilities takes charge. Two cases each consisting of three embedded cases explicate the CE of six different products.

Based on a coding process of the collected data, the two cases are analysed separately. Both minor and significant drawbacks of applying the "one-size-fits-all" approach are exposed. Given that this part of the analysis reveals a high level of uniformity across the two cases, the cross-case analysis focuses on the six embedded cases to explore which influence the "one-size-fits-all" approach has on the magnitude of the drawbacks.

As for the contributions, the paper accounts for "the one-size-fits-all" approach as a combination of managerialism embedded in the applied stage/gate approach and the fact that employees habitually draw on existing solutions. The findings illustrate that due to this "one-size-fits-all" approach being too successfully implemented, different drawbacks emerge rather late during the CE. We suggest that the consequences of the drawbacks increase if a company both creates products offering no customization options, few customization options and many customization options. The "one-size-fits-all" approach seems to blur the identification of potential drawbacks upstream of the development. Instead of using this "one-size-fits-all" approach the paper suggests that the level of customization to be offered to the customer(s) should be the focal point for clarifying the product architecture. Depending on how the chosen product architecture fits with the prevalent product architecture applied by the company and how this fits with the manufacturing-/supply chain architecture the paper suggests three different approaches to accomplish CE.

The rest of this paper is structured as follows. Following the theoretical positioning the applied method is elaborated. Next the case settings and the six CE projects are described, which is followed by the analyses. Finally, the discussion and conclusion are presented.

Theory

CE has achieved huge attention ever since Boothroyd and Dewhurst introduced the two-dimensional CE concept in the early 1980s. Fine's (1998) study of companies as "fruit flies" added a third dimension to the CE concept. A generic model to ensure a structured and coordinated CE is the "stage/gate" approach (e.g. Ulrich and Eppinger 2016). Drawing on this viewpoint the advice is to postpone decisions until sufficient understanding of the issue to be handled has been achieved. This way of managing CE is the building block for Sanders and Klein's (2012) "integrated product-industrial v-model". The generic integrated product-industrial v-model highlights a need for coordinating the development of the product, manufacturing and supply chain at different levels, which are system, sub-system, modules and components; please see Hsuan (1999) for an elaboration of the four levels. Basically, the idea is to facilitate a balance between users' needs and manufacturability. However, throughout the CE of product, manufacturing and supply chain new requirements might emerge, prioritisation might change and the achieved understanding might reveal that past decisions are now inappropriate. Due to this dynamic nature, iterations of the CE activities occur. To reduce the drawback of the iterations, which can be time-consuming and costly, Belay et al. (2014) among others suggest the application of the set-based CE approach. The set-based CE approach paves the way for identifying and analysing constraints and opportunities in the current manufacturing and supply chain set-ups and thereby takes all functional perspectives into considerations during the early stage of the CE.

Though the above generic models pave the way for establishing structures and managerial guidelines, the models do not address issues in terms of the prioritisation among different and conflicting requirements (see Mottonen et al. 2009). Some researchers highlight the role of the product architecture as the means to prioritise and coordinate the CE activities.

The role of product architecture

Fixson (2005), Sanchez (2008) and Ulrich (1995) argue that a deliberate assessment and choice of the product architecture can act as the coordination means for the decision making and thus the gradual and CE of the product, manufacturing and supply chain. Based on the work of Ulrich (1995) and Fine (1998) among others the concept of product architecture is divided into an integral-modular dimension and a closed-open dimension. Fujimoto (2013) draws on these two dimensions to put forward three kinds of product architecture, which are "open-modular", "closed-modular" and "closed-integral". This paper subscribes to the above definition of product architecture, yet we mainly focus on closed-modular and closed-integral product architecture.

The choice of product architecture influences the effectiveness of the manufacturing- and supply chain set-up as well as the involvement of external companies in the CE activities (here the captured manufacturing set-up). For instance, Petersen et al. (2005) suggest that compared with the closed-integral architecture the modular product architecture facilitates both early involvement and close collaboration with external companies during the CE. Actually, some researchers (e.g. Momme et al. 2000) emphasise a strategic necessity of using a modularised architecture if involving external companies in the development and manufacturing activities.

The assessment and choice of the product architecture should be addressed at system-, subsystem-, module- and component levels (see Hsuan 1999). For instance, a Volkswagen Golf VII represents the system level. This closed-modular design of the Golf VII consists of different subsystems as for instance windshield wiper system, braking system and the high credited MQB platform. The latter is a subsystem to introduce *"rationality across disparate products"* (Ross 2012) among all Volkswagen's conventional gasoline (TSI) and diesel (TDI) engines (incl. Seat, Skoda and Audi) having "transverse-engine and front-wheel drive". The closed modular design of the MQB platform consists of for instance a "multi-function device", which combines several functions into one unit; this module draws on closed-integral architecture, yet the multi-function device results in the compatibility of the MQB platform (Ross 2012). At the component level we find both specially designed and standard components as connectors, switches, nuts and bolts used to develop and assemble the aforementioned MFD module; standard components have open-modular architecture. Thus, by designing and applying different types of architecture at system, subsystem, module and component level companies have the opportunity to establish both a resilient supply chain (Christopher, 2016) and an effective manufacturing set-up (Slack et al. 2016).

Fine et al. (2005) consider the CE as trade-offs among the product-, manufacturing- and supply chain architecture. Some researchers draw on this viewpoint and emphasise a need for balancing the demand chain with the supply chain and manufacturing.

Demand chain versus the supply chain and manufacturing

According to Appelqvist and Gubi (2005) the design of the manufacturing- and supply chain architecture should be tailored to the demand chain in which the company offers value to the customers. Indeed, Jüttner and Christopher (2013) suggest that the manufacturing and supply chain should be designed backward and, thus, mirror the level of customization to be offered to the customers.

To assess and clarify how the manufacturing and supply chain should be tailored to create and deliver value to the customer Christopher (2016), Pagh et al. (1998) and Slack et al. (2016) call attention to the Product Differentiation Point (PPD) and Order Penetration Point (OPP). The former illustrates where the configuration (form) of the product is determined. The latter represents where (place) and when (time) the flow of materials changes from a push (speculation) to a pull (postponement) philosophy. Placing the PPD far upstream results in an early configuration of the product and, thus, increasing the number of variants to be managed in the manufacturing and supply chain. An OPP far downstream implies a forecast based manufacturing and supply chain having decentralised inventories. This combination of PPD and OPP has much in common with Taylorism and Fordism, which is appropriate if the company manufactures and supplies standard products and operates in a predictable market (e.g. Pagh et al. 1998); i.e., the product being offered to the customers have no customization options. However, customers are not a homogenous crowd for which reason it might be beneficial for a company to offer customization options to the customers (e.g. Gandhi et al. 2014). Basically, by postponing the final configuration of the product (PPD) until receiving the order (OPP) paves the way for a high level of customization.

Daaboul et al. (2016) advocate for a simultaneous determination of the PPD and OPP and emphasise that the focal point in this clarification is a detailed understanding of the customers' perceived value. To understand perceived value our research focuses on the level of customization. The level of customization illustrates whether or not a specific customer is given the opportunity to configurate the product. The level of customization is understood as a continuum. One extreme on the continuum is standard products offering no customization options to the customers, while the other extreme is configurable products offering a high level of configurations. This research operates with three levels of customization, which are "no customization options", "few customization options" and "many customization options".

Accomplishing the CE backward in accordance with the level of customization to be offered to the customers makes it necessary to proactively clarify what the level of customization will fulfil the customers' needs prior to the assessment and clarification of suitable product-, manufacturing- and supply chain architecture. The two cases presented after the method chapter illustrates the consequences of neglecting the level of customization and thus using the "one-size-fits-all" approach.

Method

As the purpose of the research is explorative the paper follows Yin's (2003) advices to use a qualitative research method. The applied abductive logic of inquiry draws on Dubois and Gadde's (2002) systematic combining implying that the theoretical conceptualisation, processing of data, drawing up the cases and analyses occur concurrently.

Due to the explorative purpose the learning opportunities from the empirical material is pivotal. Thus, the criteria for selecting the cases are tailored to enhance the learning opportunity (Stake, 2000). Diversity in terms of geographical- and cultural distance is the criterion for selecting the two instrumental cases. One case addresses the CE activities between OEM and Manufacturing-East, while the other case focuses on the CE activities involving OEM and Manufacturing-Europe. As for the three embedded cases in each of the two cases the diversity criterion is the faced architectural misfit during the CE; i.e. misfit between a suitable product architecture and the applied architecture.

The data collection consists of observations, interviews and second-hand information. Regarding the observations, one of the authors has been present at OEM in average three days per week in a five-month period and a one-month visit at Manufacturing-East. Due to political tension in the country the planned visit at Manufacturing-Europe facility is replaced by virtual observations – video-, skype- and phone meetings. Being present at the companies and taking the role of "complete observer" (see Bryman and Bell 2011) facilitates an understanding of the development activities, abbreviations and expressions applied by the employees. Likewise, being present in the companies paves the way for conducting observations in the development and manufacturing departments. In 15 meetings, lasting from 30 – 60 minutes, one of the authors acts as "observer-as-participant" (see Bryman and Bell 2011), which entails that the observations are conducted without being actively involved in handling the development activities; the agenda for these meeting addresses the progress of the development. Eight unstructured and 12 semi-structured interviews are accomplished; each of the interviews lasts on average one hour. During the interviews notes are taken and just after each interview the notes are typed up and the author's reflections are added to the document. The purpose of the unstructured interviews is to gain an understanding of the applied development approach. To conduct the semi-structured interviews an interview guide is used. In line with the systematic combing (Dubois and Gadde 2002) the drawing up of the interview guide is an iterative process between theoretical and empirical understanding, which also implies that the interview guide has been refined during the project. A gatekeeper (Bryman and Bell, 2011) supports the identification of employees to be interviewed at both OEM and at the two abroad manufacturing facilities. Final, the second-hand information consists of data related to product development (stage/gate model, development time, routings and BOM), manufacturing (layouts, volume/ variety, capacity, cost and leadtimes) and supply chains (delivery time, OPP, PPD and inventories).

By systematically combining our empirical- and theoretical understanding, the collected data are coded; the coding of data has much in common with table 1, which summaries the case chapter. Based on this coding, each of the two cases is analysed separately to expose different kinds of drawbacks from applying the one-size-fits-all approach in the development with Manufacturing-East and Manufacturing-Europe, respectively. The analysis reveals a great level of uniformity in terms of conducting the CE in the OEM/Manufacturing-East and OEM/Manufacturing-Europe settings. Both minor and significant drawbacks of applying the "one-size-fits-all" are exposed and by focusing on these different drawbacks a pattern across the six embedded cases emerges. In other words, the cross-case analysis focuses on the six embedded cases to explore which influence the "one-size-fits-all" approach has on the magnitude of the drawbacks.

Case

OEM, the case company, is a huge company located in a high-wage area operating in the consumer goods industry. OEM has been within the industry since the early eighties and during this period the company has developed a great many products. At present time (2016) OEM has 350 employees at the Headquarters.

OEM acquired Manufacturing-East in 2005. At present Manufacturing-East employs 500 employees and focuses on developing and manufacturing various products. Manufacturing-East consists of several departments as for instance product development, quality assurance and control, purchasing, manufacturing and assembly.

At the outset, Manufacturing-Europe acted as supplier, but OEM acquired full ownership of the facilities in 2008. Currently, Manufacturing-Europe has 320 employees. The main focus is manufacturing and participation in the development of different products. Manufacturing-Europe is divided into a number of departments - product development, quality assurance and control, purchasing, manufacturing and assembly.

First, the settings of the development are explained after which a table presents the two cases and six embedded cases being studied.

The settings of the development

OEM and the two captured manufacturing facilities make use of a standardised operating procedure to accomplish the development; in daily language, the "business-as-usual" approach. The business-as-usual approach consists of four stages and three gate meetings. The first stage addresses an identification and clarification of the product idea, which ends with drawing up a draft version of the design proposals. At the first gate meeting top management decides whether or not the project should be terminated or approved for further development. As for the second stage, the focal point is to draw up a "concept-plan"; another jargon applied by the employees. During the second stage, the design proposal is elaborated and functional specifications as well as 3D drawings are created and documented in the concept-plan. A gate meeting is conducted before OEM hands over the concept-plan to either Manufacturing-East or Manufacturing-Europe. The handed over information is applied by the development department to design and manufacture a prototype. During this third stage, one or more employees from OEM conduct ongoing follow-up meetings to proactively ensure that the prototype is in accordance with the functional specifications. Anyhow, after finalising the manufacturing of the prototype the third gate meeting addresses the compliance between the functional specifications and the physical prototype. An approval entails the drawing up of the necessary manufacturing and supply chain specifications; this is documented in a "master sample".

In the past OEM has developed and manufactured various products, but no of these developed products has offered any customization options to the customers. It implies that OEM and the two manufacturing facilities are tailored to handle products having low variety and high volume.

The employees designing the products do not pay special attention to the product architecture and habitually they are developing products having a closed-integral product architecture. During the development the employees designing the products are accustomed to consider the manufacturing layout and supply chain structures as being fixed, which entails that manufacturing and supply issues are only sporadically considered during the development.

As for both manufacturing facilities products are manufactured in batches, but neither Manufacturing-East nor Manufacturing-Europe operates with standard batch sizes. The layout of the manufacturing facilities is mainly product line layout (tailored to high volume and low variety), yet few departments at Manufacturing-East applies a more flexible layout. The manufacturing leadtime in both facilitates is four to six weeks.

Due to different geographical distance the two manufacturing facilities do not operate with the same supply chain set-up. The delivery leadtime from Manufacturing-East is in average six weeks, which implies that the logistic leadtime is between 10 – 12 weeks. Accordingly, OEM operates with three different supply chain set-ups in terms of delivering products to the customers; 1) Make-to-Stock (MTS) concept, where finished goods inventory is placed next to the Headquarters: 2) MTS at the Manufacturing-East location: 3) Make-to-order (MTO) concept entailing that both the manufacturing and delivering activities are order-based. Regarding Manufacturing-Europe, the deliveries are noticeably faster, which entail that the logistics leadtime is approximately six to seven weeks. Two different supply chain set-ups are used to deliver products to the customers; 1) MTS, where finish products are placed at inventory facilities close to the Headquarters: 2) MTO, where manufacturing and deliveries are postponed until an order is received.

The six development projects being studied

Two cases each having three embedded cases present how OEM, in collaboration with either Manufacturing-East or Manufacturing-Europe, develops six different products. The leftmost column is the designated case name followed by the applied managerial approach. The next column presents the architectural misfit between a suitable product architecture and the applied architecture. The middle column summarises the level of customization and CE during the development, after which the development time and number of iterations appear. The rightmost column describes how OEM and Manufacturing-East/Europe perceive the outcome of the development.

Table 1. The two cases and six embedded cases.

OEM and Manufacturing-East						
Case	Development approach	Architectural misfit	Applied product architecture & alignment among product/manufacturing & supply chain	Develop-ment time	No. of iterations	Development outcome
M-East 1	Business-as-usual	Low	No customization and use known integral product architecture. Achieve alignment among product/manufacturing/ supply chain.	Three months	One minor iteration	Successful
M-East 2	Light version of Business-as-usual	Some	No customization and use known integral product architecture, yet employees struggle to grasp interfaces at subsystem and modules levels. Achieve alignment among product/manufacturing/-supply chain.	So far, eight months	Three major iterations	Still awaiting final approval
M-East 3	Business-as-usual	Some	No customization and use known integral product architecture. Achieve alignment between product and manufacturing, but misalignment in terms of supply chain.	Seven months	Two minor and three major iterations	Successful, yet supply chain is inefficient
OEM and Manufacturing-Europe						
Case	Development approach	Architectural misfit	Applied product architecture & alignment among product/manufacturing & supply chain	Develop-ment time	No. of iterations	Development Outcome
M-Euro 1	Business-as-usual	Low	No customization, but design a new integral product architecture; the concurrent design of subsystems reduces the number and extent the iterations.	Three months	One minor iteration	Successful
M-Euro 2	Business-as-usual; after two major iterations an external specialist is involved	Some	Few customization options, yet at the outset, known integral product architecture is applied. An external consultant suggests the application of a more closed-modularised architecture. Employees are capable of adapting the product architecture to the existing manufacturing and supply chain.	Five months	One minor and three major iterations	Successful
M-Euro 3	Business-as-usual	High	Many customization options; four sub-systems are identified, and by habit an integral product architecture is applied. Employees are incapable of aligning the four sub-systems entailing a non-functional product. Misalignment in relation to both the manufacturing and supply chain.	Seven months	Five major iterations	Unsuccessful Termination of the project after seven months

Analysis

This paper strives to explicate the drawbacks of applying the "one-size-fits-all" approach to CE; the "one-size-fits-all" approach is equivalent to the business-as-usual approach in the six cases.

The two cases reveal some differences in terms of how OEM collaborates and accomplishes the CE activities with Manufacturing-East and Manufacturing-Europe, respectively. Manufacturing-Europe is the preferred collaborator if OEM strives to break new ground for the products being developed. In addition, the analyses indicate that Manufacturing-Europe is working more systematically throughout the development and that the relative short geographical distance makes it more affordable for the employees from Headquarters to regularly carry out evaluations of the development projects at the European facilities. Nevertheless, despite these differences, culture diversities and the facts that managers and employees in the two facilities do neither have the same educational background nor experience, the applied "one-size-fits-all" approached resulted in a striking uniformity between the two cases. Apparently, the "one-size-fits-all" approach has a deterministic influence on the way OEM and Manufacturing-East/-Europe accomplish the CE activities; this illustrates an example of managerialism, a phenomenon which has been overlooked in the literature (Dekkers et al. 2013).

If focusing on the drawbacks of applying the "one-size-fits-all" approach a pattern across the cases emerges. From the beginning, all six developments were handled as regular projects. In the same vein, the analyses reveal that both the employees at OEM and at Manufacturing-East/Europe made use of well-known product specifications and the existing set-ups in the manufacturing- and supply chain when creating the solutions. This orchestration of existing and well-known specifications had huge influence on the clarification and creation of the product-, manufacturing- and supply chain architecture.

The faced complexity of M-East 1 and M-Euro 1 was as expected low, but the complexity of the M-East 2, M-East 3 and M-Euro 2 turned out to be higher than expected. The complexity to be handled in the M-Euro 3 was much higher than expected. In addition, with the exception of M-East 1 and M-Euro 1 the products being developed were not systematically addressed on a system-, subsystems-, modules- and components level. Accordingly, in some of the developments the drawn up functional- and/or detailed technical specifications proved incomplete. It entails that the involved employees did not achieve a sufficient understanding to facilitate a transformation of functional and technical features into a workable prototype.

The M-East 1 and M-Euro 1 developments were completed successfully and only minor drawbacks occurred. OEM and Manufacturing-East/Europe were capable of constructing usable functional and technical specification, which implies that the necessary iterations to ensure manufacturability were easily conducted.

Because a higher complexity than expected from the outset, the M-East 2, M-East 3 and M-Euro 2 developments caused some significant drawbacks. As for the M-East 2, the project was regarded as being straightforward, which implies that the clarification of functional features and drawing up of the necessary specifications were accomplished in a rush. It turned out that OEM and Manufacturing-East were incapable of achieving a sufficient understanding to ensure a smooth transition between concept development and the creation of the prototype. Despite the M-East 3 and M-Euro 2 projects strictly followed the "one-size-fits-all" approach, the analyses reveal a similar lack of understanding in the transition between concept development and creation of the prototype. This knowledge gap resulted in a number of significant drawbacks and major iterations to facilitate an acceptable level of manufacturability. The analyses indicate that these drawbacks occurred because the employees did not address the pros and cons of the chosen product architecture. Habitually, the employees drew on an integral architecture and obviously it was a challenge for them to develop workable interfaces among system, subsystems and module levels. Likewise, the existing manufacturing- and supply chain set-up were not addressed upstream in the development. However, in the M-East 2 and M-Euro 2 projects the employees were capable of adapting the applied product architecture to the existing manufacturing- and supply chain set-up, which paved the way for achieving an acceptable manufacturability. The opposite appears from the M-East 3 project, where the employees were incapable of successfully adapting the product architecture to the supply chain set-up; this had a negative influence on manufacturability.

Regarding the M-Euro 3 project signification drawbacks and major iterations occurred in a steady stream; because the two interacting companies were incapable of developing a workable prototype, the project was terminated. The problems are not just related to a knowledge gap between the concept development and the physical creation of a workable prototype. A contributing factor to this unsuccessful development is the fact that neither OEM nor Manufacturing-Europe gained a sufficient understanding of the nexus between the "intended level of customization" and the choice of product architecture and also how this would influence the manufacturing- and supply chain architecture. For instance, the three "standardised" supply chain set-ups have different placement of the OPP, but the PPD is always far upstream, which implies that the three supply chain set-ups are tailored to fulfil the expected sales volume and not to a product architecture offering some level of customization. In addition to this blurred conceptual clarification Manufacturing-Europe did not have sufficient knowledge in terms of designing the interfaces among subsystems, modules and components and how to manufacturing these. To achieve manufacturability when handling a project like M-Euro 3, it seems pivotal to gain a detailed understanding of an appropriate architecture of the product to be developed and to simultaneously conduct the CE of product-, manufacturing- and supply chain architecture; obviously, OEM and Manufacturing-Europe were incapable of revealing misfits in this regard.

Discussion and conclusion

At the outset the purpose of this research was to empirically study the drawbacks of applying the "one-size-fits-all" approach and use this understanding to suggest a method to overcome the identified drawbacks.

The above analyses of the CE activities in globalised settings highlight major drawbacks of applying the "one-size-fits-all" approach. OEM and the two manufacturing facilities strictly follow the stage/gate approach. Likewise, habitually the employees draw on well-known technical solutions to prepare functional specifications and also during the manufacturing of the workable prototype. Hence, our findings suggest that the application of the "one-size-fits-all" approach throughout the development is a combination of following the advices embedded in stage/gate method (e.g. Ulrich and Eppinger 2016) and the facts that all employees decidedly draw on existing technical solutions.

As it appears from the analyses, two of the six projects are accomplished without significant drawbacks and only minor iterations are necessary to ensure manufacturability. These two projects have in common that the functional features and technical specifications fit with the well-known product-, manufacturing and supply chain architecture. In other words, throughout the development the employees are on safe ground and they are capable of following the "gambling rule", which is central in the funnel analogy *"When uncertainties are high, keep the investment (stake) low; as the uncertainties reduce, increase the investment"* (Baxter 1999). As for the three projects having significant drawbacks and major iteration neither OEM nor the involved manufacturing facility is capable of understanding the consequences of using the "standard integral product architecture" before starting up the manufacturing of the prototypes. However, after time-consuming and costly modifications of the product architecture an acceptable balance between users' needs and manufacturability is achieved. Regarding the last project, the one being terminated the consequences of applying the "one-size-fits-all" approach becomes noticeable. First, the chosen product architecture is inappropriate to offer customization options to the customers. Second, the drawing up of the functional features and specifications do not consider issues related to the manufacturing- and supply chain architecture. Hence, rather late during the development a number of drawbacks and major iterations occur in a steady stream.

Our findings echo the usefulness of applying the stage/gate approach (e.g. Ulrich and Eppinger 2016) to handle the CE activities. Likewise, we appreciate Sanders and Klein's (2012) integrated product-industrial v-model as this approach sheds light on the benefits of addressing the CE activities at system-, sub-system-, module-, and component level. However, as it appears in the above the "one-size-fits-all" stage/gate (or integrated product-industrial v-model) approach is inappropriate if the company both develops standard products offering no customization options, products having few customization options and final products providing many customization options. Thus, one can argue that the stage/gate way of thinking is too successfully implemented in OEM and in the two manufacturing facilities. In four out of the six projects being analysed the "one-size-fits-all" approach either results in costly and time-consuming iterations or termination of the CE. Belay et al. (2014) among other suggest the application of a set-based CE approach to ensure an identification and analysis of potential drawbacks upstream of the development. Actually, in three of the aforementioned projects the company invests a lot of resources upstream of the development, which means that different issues are taken into consideration before finalising the concept and clarification of functional features. Apparently, the "one-size-fits-all" approach blurs the identification of all potential drawbacks upstream of the development.

We appreciate that the stage/gate way of thinking and the set-based CE method to postpone decisions are valuable in terms of establishing structures and managerial guidelines. However, the practical realities revealed in this study illustrate that companies struggle to understand and prioritise among all the requirements (like Mottonen et al. 2009). Some researchers (e.g. Fixson 2005) highlight the role of the product architecture as the means to prioritise and coordinate the CE activities, others address a concurrent alignment among product-, manufacturing- and supply chain architecture (e.g. Fine 1998), while Appelqvist and Gubi (2005) suggest to focus on the demand chain. Findings in this study indicate that it seems appropriate to study in detail what kind of value the product being developed should offer to the customer(s). This paper suggests focusing on the level of customization offered to the customer(s). Based on this clarification the company should tailor the product architecture to fulfil this requirement. If the chosen product architecture has much in common with the prevalent product architecture applied by the company the CE is straightforward. However, if the chosen product architecture differs from the prevalent product architecture the next issue to be analysed is whether or not the chosen product architecture can be adapted and thereby aligned to the existing manufacturing and supply chain architecture. If the chosen product architecture cannot be adapted without compromising the offering to the customer(s) a full scale development has to be accomplished. This full scale development implies that the level of customization determines the product architecture and throughout the development, the accomplished CE activities should successively pave the way for aligning the product-, manufacturing- and supply chain architecture.

This orchestration of the customers as the focal point for the assessment and clarification of the product-, manufacturing- and supply chain architecture indicates a need for adding a customer dimension to Fine's (2000, 218) statement *"once one recognizes the strategic nature of supply chain design one feels almost compelled to integrate it with product and process development"*; as Peter Drucker reminds us *"the customer is the foundation of a business"*.

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Biography

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