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TYPES OF PARTLY CONFIGURABLE PRODUCTS IN HIGH-VARIETY, LOW-VOLUME CONTEXT

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ABSTRACT

Research on partly configurable products is emerging. Key concepts of these types of products have been scarcely synthetized, as definitions of partly configurable products in high-variety, low-volume industrial context are limited. These products incorporate modular and integral designs, which calls for an overview on the relations of key concepts defining them. The problem is approached through an exploratory literature review, which allowed an overview of the key concepts over product modularity and partly configurable products. Those were synthetized further define partly configurable products. As a result, four types of partly configurable products are given. This review supports vantage over the key concepts and their relations for reuse with partly configurable products in academia. For practitioners the presented attributes and given examples support in understanding of concepts and their relations with partly configurable products.

Keywords: Partly configurable product, Design management, Product architecture, Product structuring

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1 INTRODUCTION

Mikkola & Gassmann (2003) propose a function to measure the level of modularity in a product architecture. In the function, components observed in product´s bill of material (previously utilized or library components, and components without prior knowledge and application), interfaces (degree of interface standardization and specification defining compatibility between components), degree of coupling (describing number of shared interfaces with other components), and substitutability (designing product architecture with desirable combination of components to gain economies of substitution) are utilized measure the level of modularity. (Mikkola & Gassmann, 2003) Similarly, Markworth et al. (2017) propose a five-step model to support engineer-to-order (ETO) companies by identifying improvements with modular products without compromising the required flexibility to make customized ETO solutions. After visualizing and modelling the focal product family, previous configure-to-order (CTO) and ETO customizations are mapped on the product family, followed by identification of future customization requirements, which results in identifying product module improvement potential. The aim of the model is to improve product configurability while considering customized solutions and flexibility of the product. (Markworth et al., 2017)

Within high-variety and low-volume (HVLV) context product and production development is important (Adlin, 2022), hence explaining the reasoning why the modules exist in the product, and how those are related to the context where the business is operating in is important. With partly configurable products the aim is to find suitable fit to the customer´s and supplier´s operating context. Degree of modularity model by Mikkola & Gassmann (2003) focuses on study of existing products´ level of modularity in a product architecture – or alternatively, level of integral product architecture in the product. Similarly, the five-step model by Markworth et al. (2017) is to improve modularization and configurability in ETO companies. In HVLV context with industrial capital goods, such as cruise vessels, managing product and subsequent delivery competitively calls for aligning multitude of designs, business goals, and stakeholders to be managed over an extended timespan. These elements and business constraints give rise to explain how to support product design, management, and configurability.

This reasoning calls for answering a question: What are partly configurable products? To answer this, the focus of this conceptual paper is on the key concepts over partly configurable products and relations of those. The review focuses on the key concepts of partly configurable products obtained through literature review, and the phenomena on relations between those concepts, without focusing on tools, methods, or processes for managing or developing such products. To answer the main question, chapter 'Research methodology' explains approach over exploratory literature review and presents supporting questions for the main question. Chapter 'Modularity of products' presents supporting findings from literature included for types, which are then discussed in chapter 'Discussion' with answers to research questions and explains novelty of the publication. Chapter 'Conclusion' provides remarks regarding the literature review. Additionally, chapter 'Limitations' considers trade-offs of the publication, followed by chapter 'Future work'.

2 RESEARCH METHODOLOGY

The overall research objective is to answer to the main question: What are partly configurable products? Reaching this objective is supported by the descriptions of key concepts regarding modularity of products, relations of the concepts and their inherent hierarchy, and literature over partly configurable products. Hypothesis for this paper is ‘modular product’s definitions are also applicable to partly configurable products.’ To answer the overall objective of the research, the following research questions were formulated:

1. What are the existing key concepts regarding partly configurable products?
2. How are the key concepts related to each other?

To answer the research questions an exploratory literature review was conducted. The review was carried out in three distinct steps: planning the review, executing it accordingly, and then analysing the results (de Almeida Biolchini et al., 2007), which aided in describing and justifying the findings

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through comparison of found studies (Blessing & Chakrabarti, 2009). The review protocol specified research questions and methods to execute the review (de Almeida Biolchini et al., 2007). Scopus search parameters for title were '("partly configurable" OR "design reuse") OR (modular AND (engineering OR system OR "product structure" OR "product family"))', for abstract '(define OR definition OR configure OR partitioning OR knowledge) OR (PSS OR "product service system")', and for keywords '("design method" OR "product design" OR "engineering design") OR (modularization) OR ("product development" OR "product variety")'. Search parameters were selected to find control publication (publication 11, see list of publications reviewed below), and other relevant publications to support answering the research questions.

Empirical and conceptual publications, and journal and conference publications were qualified, however no grey literature was considered for this review. Accepted publications had to present the following, as inclusion criteria: present configurable product (to any extent) in manufacturing, or industrial context. The search resulted in 112 publications utilizing Scopus (99 of 112) and Web of Science (13 of 112, where control not available) database sources in August and September of 2022. After removing 10 publication duplicates found in the 2 different sources, and after removing 5 publications from possibly unethical publisher (Beall, 2022, accessed September 2022), the final set of publications for analysis was 97 publications. The final analysis set was then screened qualitatively using 3 filters, first by reading title, abstract and keywords, second by reading introduction and conclusion, and third by reading the complete article. Aim of screening was to select publications for the exploratory literature review. Additionally, backward snowballing was utilized to capture relevant referenced information (Wohlin, 2014) regarding the research questions and the objective. Same inclusion criteria were applied for the publications retrieved by snowballing. Additional 7 publications were retrieved through backward snowballing. Thus, the final set of selected publications was 25 publications. Utilized publications: (1) (Belkadi et al., 2016), (2) (Brière-Côté et al., 2010), (3) (Bruun et al., 2013), (4) (Bruun et al., 2015), (5) (Doe, 2021), (6) (Giddaluru et al., 2015), (7) (Hanna et al., 2020), (8) (Hofer & Halman, 2005), (9) (Juuti et al., 2019), (10) (Mahapatra et al., 2012), (11) (Pakkanen et al., 2021), (12) (Pakkanen, Huhtala, et al., 2016), (13) (Pakkanen et al., 2015), (14) (Pakkanen, Juuti, et al., 2016), (15) (Pakkanen et al., 2019), (16) (Shamsuzzoha & Helo, 2017), (17) (Wang et al., 2011), (18) (Yan & Stewart, 2010). Snowballed publications: (19) (Andreasen, 2011), (20) (Duffy & Ferns, 1999), (21) (Juuti, 2008), (22) (Juuti & Lehtonen, 2006), (23) (Murphy & Gorchels, 1996), (24) (Pahl et al., 2006), (25) (Ulrich, 1995). The key definitions in the selected literature are presented in chapter 'Modularity of products'. An ontological representation, a synthesis of definitions as shared conceptualization (Gruber, 1995; Tursi et al., 2009) is included in the chapter.

3 MODULARITY OF PRODUCTS

Development of customisable products is usually based on modularisation that can be considered as tasks of product management (Pakkanen et al., 2021), which can provide a competitive approach to well-serve the markets (Murphy & Gorchels, 1996). Product management participates also in determining the strategic direction of the products (Murphy & Gorchels, 1996). The product management need is heightened with products engaged with modularisation in long-term perspective. Modularisation encapsulates complexity into manageable parts (Bruun et al., 2013), either at module level (Shamsuzzoha & Helo, 2017, Belkadi et al., 2016), or at set of set of modules level (Pakkanen et al., 2015). Modularisation can be presented as product development strategy increasing design reuse (Pakkanen, Huhtala, et al., 2016), where dividing product into functional modules is a well-known approach (Juuti et al., 2019). Modularisation aims creating variety for customer, reduce complexity of company´s operations, and at the same time have commonality between module variants (Andreasen, 2011). For implementation of such modular strategy, a product needs further division. Modules can be physical structures that have correspondence to functional structures (Giddaluru et al., 2015), or representations of conceptual grouping of components that are identifiable and replaceable (Belkadi et al., 2016), which collectively can be called as set of modules, that enable creation product variety (Pakkanen et al., 2019, Pakkanen, Juuti, et al., 2016). Modularisation increases design reuse, which allows previously designed interfaces, components, modules, or solutions to be utilized in a design situation (Pakkanen et al., 2019), in which design reuse is synonymous to design by reuse. Design for

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reuse is identification and extraction of possible reusable knowledge fragments and enhancing that content (Duffy & Ferns, 1999), which is enabler of design by reuse (Pakkanen, Huhtala, et al., 2016).

Modular design, and design by reuse call for connectivity and reduction of complexity between components and modules. Interfaces can be connections between subsystems or components (Bruun et al., 2015, Yan & Stewart, 2010), that allow independence and interchangeability (Pakkanen et al., 2019) and reuse of modules (Wang et al., 2011). Meeting interface conditions (Doe, 2021) enables interchangeability. Benefits of modular design are derived in long-term from increased external variety without the expense over engineering efforts. Modularity can be characterized as having combinability, changeability, substitutability, and standardization of modules (Wang et al., 2011) for reuse (Brière-Côté et al., 2010, Yan & Stewart, 2010). A principle of modularity is that parts or modules can be treated as logical units (Bruun et al., 2015), where product families can be generated from platform design by selection of modules (Giddaluru et al., 2015).

3.1 Conceptual level of modular products

Modular product management occurs a more concrete divisional level, but also at conceptual level of platforms, families, and architecture. A modular design platform has finite number of components and associated interfaces allowing variability in a common structure (Mahapatra et al., 2012) through use modules (Shamsuzzoha & Helo, 2017) that enable reuse and interchangeability (Yan & Stewart, 2010). Products in product family share a common platform (Bruun et al., 2013), that are basis on which a product family is developed on (Bruun et al., 2015). A module-based product family is derived from a common platform by adding, or removing functional modules (Shamsuzzoha & Helo, 2017), and use of modules should be enabled by a product family (Pakkanen, Juuti, et al., 2016). Architecture explains building blocks of the product (Bruun et al., 2013) that have high degree of independence between the modules in a modular product architecture (Hofer & Halman, 2005). Architecture represents layout scheme, and their interactions through interfaces (Giddaluru et al., 2015, Pakkanen et al., 2015). Product architecture thus holds information on how many variants a product family consists of, and how many components, and how those interact with each other (Bruun et al., 2013). To maintain reusability, architecture consider also other possible engineering restrictions (Pakkanen et al., 2019) that may apply. Modular architectures, slot, bus, and sectional, allow required changes, that are typically associated with product´s function to be localized to minimum number of components (Ulrich, 1995). Conceptual level has certain hierarchy, that can be concretized to more manageable concept. Product structure is a set of objects and their relationships representing structural aspects of a product (Brière-Côté et al., 2010) being more like a hierarchical presentation (Pakkanen, Juuti, et al., 2016). When external variety is high, modular product structures are used to reduce internal variety (Hanna et al., 2020).

3.2 Logic and reasoning of modular products

To bind the complexity of product´s management and engineering, whether developing a new or existing product, there are set of internal and external restrictions that support the effort. Partitioning logic provides reasoning for module division of a product family (Pakkanen et al., 2015), contributed by two drivers, customer needs and considerations, and business environment factors (Pakkanen, Juuti, et al., 2016, Pakkanen et al., 2019). These drivers divide modular system into smaller engineering entities, to variability needs from customer environment, and to product structuring principles from business environment (Pakkanen et al., 2019). Partitioning logic results in a model describing the product´s architecture, modules, and interfaces (Pakkanen et al., 2019). The logic captures essence and reasoning for the product offering, that can be further concretized with reasoning and division. Design reasoning path aims to document and support understanding of product family decomposition. It describes the reasoning chain to a specific customer need, thus explaining need for variation through a generic element. In the reasoning path parts and assemblies (that can be standard, modular with variants, or one-of-a-kind element) are organised according to the generic element they belong to. (Pakkanen et al., 2015)

3.3 Elements of modular products

The elements depict modules and parts, that are arranged according to variation needs constituting ultimately a product. Generic element fulfils one variation need with aim to encapsulate effect of customer variation need within the element, to which the product is divided to (Pakkanen, Juuti, et al.,

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2016). If restructuring a generic element does not allow standardisation, then the element is considered as one-of-a-kind element, whereas standard element can be considered as fully configurable element (Pakkanen et al., 2015). Configurable part (element) can contain standard and configurable parts to achieve variability (Juuti & Lehtonen, 2006). Standard element is a common element for different variants with no relations to customer needs, and standardisation can be considered as enabler of modularisation (Pakkanen et al., 2015). Standard elements can be reused in many products as such, whereas one-of-a-kind element is designed for a particular instance without objective to achieve standard part as a result (Juuti & Lehtonen, 2006). Thus, one-of-a-kind element can be considered as a non-module that Pahl et al. (2006) describe as customer-specific module that are not included in the modular system.

The interchangeability of the elements allows the variety in the offering but does not explain engineering efforts for the order-delivery process. Product configuration is a process reusing designs to deliver customized products (Brière-Côté et al., 2010, Belkadi et al., 2016) whilst meeting factors from customer and business environments (Brière-Côté et al., 2010). Configuration knowledge is utilized to define customer specific variants (Pakkanen et al., 2019). Sales is supported through this knowledge in describing the modules to be selected against certain customer needs, where generic elements are connected to customer needs, of which intersection in a matrix format represents configuration knowledge (Pakkanen, Juuti, et al., 2016). ETO is carried out when customer orders the product and requires modifying existing product elements or developing new elements (Pakkanen et al., 2019), and are specially designed according to distinctive customer requirements (Brière-Côté et al., 2010). ETO products can result in having integral product architecture, which Ulrich (1995) describe as including a complex, being not one-to-one, mapping from functional elements to their respective components and related interfaces. Utilizing reusable elements, a product can be configured and can be considered as CTO, that can include selection, replacement, or exclusion of other elements (Pakkanen et al., 2019) in the product configuration process. Derive-to-order (DTO) elements are pre-engineered elements lacking detailed engineering but follow product structuring restrictions and principles (Pakkanen et al., 2019). DTO share partial resemblance to Pahl et al. (2006) described adaptive modules which allow for unpredictable circumstances, and of which dimensions are not fully fixed.

3.4 A partly configurable modular product

At a product level, catering to an individual customer with a modular product including a customer-specific design differentiates partly configurable products from standardized, mass customized, and unique products. A product becomes partly configurable when the fully configurable modular structure is introduced with customer specific element (Juuti, 2008). According to Pakkanen et al. (2021) partly configurable products enable ETO and unique solutions while obeying architectural and interface restrictions, and partly configurable product structure allows delivery specific elements. Product family can be considered partly configurable, when one-off solution is introduced to the modular system (Pakkanen et al., 2021). Partly configurable element can also include partly configurable parts (Juuti & Lehtonen, 2006).

Fully and partly configurable products, and their differences can be understood by understanding the core definitions, attributes, and their interdependencies. Pakkanen et al. (2015) describe the partitioning logic, set of modules, interfaces, architecture, and configuration knowledge as the key design information elements of a modular product family, also referred by Pakkanen et al. (2019) as building blocks of modular system. By highlighting these key information elements, we synthetize and describe the partly configurable product, its key attributes, and their relations in next chapter.

3.5 Synthesis on partly configurable products

The building blocks of modular system (Pakkanen et al., 2019) are hereafter referred as 'Module System'. Module System and ETO element are the key attributes of partly configurable products.

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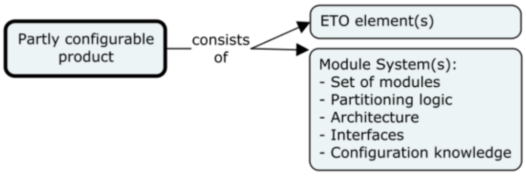

Figure 1. Attributes of a partly configurable product.

As in figure 1, partly configurable product (bolded box) consists of mix of Module Systems, and ETO elements. As proposed by Juuti & Lehtonen (2006) the one-of-a-kind elements do not fit to all types of products, whereas other products are fully unique and one-of-a-kind. This suggests the business environment gives rise in introducing one-of-a-kind elements to otherwise modular or configurable products. Reasoning for introducing such ETO element is a product management decision arising from business environment. ETO element in a partly configurable product should obey architectural decisions (Pakkanen et al., 2021), suggesting that one-of-a-kind ETO element should obey modular product´s architectural decisions and rules. However, one-of-a-kind element can be considered as ETO element, that can have an integral product's architecture, depending on the extent of the element, or such elements in a product. Thus, the ETO element can be a unique-one-of-a-kind solution, or a pre-engineered DTO solution. Module System (with its key elements) and ETO elements is what extends, and thus differentiates partly configurable products from a 'modular product', or an 'ETO product'. Partitioning logic supports the module division for a product family based on customer´s needs and on business environment. The logic results thus describing the architecture, modules (as set of modules), and interfaces of the product by capturing the essence for the product offering. Aiming towards configurability of the product, a design reasoning path connects customer´s need, as a variation need, and modules through a generic element which encapsulates the effect of the variation need to the product configuration. The intersection between modules and variation needs in a generic element represent the configuration knowledge. Design reasoning path thus supports understanding the composition of the product and allows configurability. These combined, following arrows in figure 1, partly configurable product consists of Module System(s) and ETO element(s).

Aim was to answer, ‘What are partly configurable products?’ Juuti (2008) described partly configurable product is a fully configurable product introduced with customer specific element, and Pakkanen et al. (2021) added that the customer specific solution should obey architectural and interface restrictions where it is allowed in the product structure. This objective is answered by the four different types below. Juuti (2008) description has fit to the types A.2 and C of partly configurable product below, and Pakkanen et al. (2021) description has fit to the types A.1, and type B as in Figure 2. In figure 2 the box 'Customer specific ETO' (as customer variation need) explains with arrows through types of partly configurable products whether the customer specific ETO requirement affects the ETO element(s), or the Module System(s) of the partly configurable product.

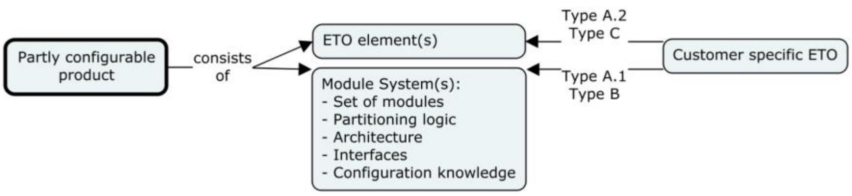

Figure 2. Different types of partly configurable products.

Types A.1 and A.2 of partly configurable product can be fully configurable for order-delivery process, where unique customer specific ETO solutions are allowed in ordering process, as depicted in figure 2. The unique customer specific solution can affect within a Module System, or outside the Module System. Whether the customer specific solution should be part of Module System obeying product´s rules and restrictions, or not, is to be decided by the seller´s business. In other words, product has been fully modularized and enabled for configurability without need for ETO in order-delivery process, however one-of-a-kind elements are allowed for the delivery. An elevator is an example of type A.1, where a customer requests and seller allow for localized safety equipment over the standard solution suggested initially by the seller. Similarly due to business environment in the elevator example,

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localized safety equipment solution would not be part of the Module System as with type A.2. This is due to unforeseeable requirement by a customer, for example.

Type B partly configurable product is not yet fully configurable, but remainder of modules enabling full configurability for order-delivery process have been pre-engineered already. In other words, some parts of the product have been modularized, and some remain as DTO (that do follow rules and restrictions of the Module System), thus ETO is required in the order-delivery process, as depicted in figure 2. The resulting product can be a fully configurable product, or as type A.1 or A.2, depending on the seller´s business decisions. An upgrade or a retrofit on an elevator is an example of type B, where a customer is approached in upgrading their equipment with a pre-engineered solution by the seller.

Type C partly configurable product will not be fully configurable ultimately. In other words, modules and Module Systems do exist, but due to the product's nature and complexity, and given business environment, the product will always remain as partly configurable. In this case a substantial portion of the product remains as customer specific ETO, however modules or Module Systems do exist in the product. A cruise vessel is a representation of a product where different customers' requirements vary resulting the seller to modularize and standardize only select areas of the product, such as elevators, and customizing majority of the product. A cruise vessel is an example of type C product, as in figure 2.

The four different types (A.1, A.2, B, and C) of partly configurable products point out that there are different decisions to be made over the product due to the business environment constraints where the company operates. Those constraints could be related to limited resources available for engineering with product delivery, or management of it. The constraints may arise from limited knowledge over customers´ or suppliers´ needs, which may render modularisation of such product challenging in succeeding in increasing external product variety and reducing internal product variety. With the given types, and examples of partly configurable capital goods, these constraints may play a role in the decisions over the product. These are operative decisions that can manifest in the product, and are rooted in internal and external business environment the company is operating in. If design variation is on module, it effects the Module System defining the module, rendering such design variations important for product management. This is due to Module System not being fixed in its nature within HVLV context. To conclude, with types A.2 and C it is the business´ decision whether the one-of-a-kind ETO element will ultimately be left in or out of the Module System, whereas with type A.1 and B the element consisting of ETO will ultimately be part of the Module System.

4 DISCUSSION

Degree of modularity function suggested by Mikkola & Gassmann (2003) is not sufficient in supporting a business to increase its competitiveness. With partly configurable products the key is to plan and decide which elements of the product are part of the module system, and which shall remain as non-modules. The set of modules consist of the configurable elements that increase external variety, and of the standard elements that do not increase external variety. The generic element is a representation and encapsulation of the different elements (parts, subassemblies, and modules) to fulfil a customer variation need while limiting the variation need in the element itself, where design reasoning path reasons why the generic element exists. Thus, the generic element can be of conceptual nature. As the generic element is connected to a variation need, this information can be then utilized as configuration knowledge for product configurations. The design reasoning path can be considered customer-borne reasoning for the common platform, which is further supported by the partitioning logic in reasoning the module division of it. Partitioning logic provides environment-borne reasoning from network of stakeholders for the module division. Thus, reasoning for division of modules is supported by design reasoning path and partitioning logic from the given environments, and the product decisions correlate and are justified through importance of reasoning and logic. The standard elements can be considered as the basis enabling modularisation due to being present throughout the common platform, ultimately representing themselves as parts of the product family and its products. Intention of modular product architecture, and thus of modular products is to increase external product variety while limiting internal product variety. Design by reuse through design reuse (Pakkanen, Huhtala, et al., 2016) where 'design by reuse' is synonymous to enabling configurability, and where

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‘design reuse’ is enabled by the reusable elements of the design, synonymous to set of modules. Architecture is the layout view of the product, and explanation of its set of modules through interfaces and module interactions, ruling and restricting the product further in a logical manner.

Answer to first research question, ‘What are the existing key concepts regarding partly configurable products?’ As in figure 1, those are Module System (set of modules, partitioning logic, architecture, interfaces, and configuration knowledge) and ETO elements. They bring justification, reasoning, and logic into defining types of partly configurable products through understanding modular products and ETO elements as discussed above. Answer to second research question, ‘How are the key concepts related to each other?’, is answered through the synthesis for figure 1. The synthesis provides on overview of key definitions, and interrelation of those. The presented hypothesis remains valid, however with partly configurable products one-of-a-kind elements (as non-modules), that can have an integral product architecture, are a necessity to explain the phenomena.

Novelty of this paper is the recognition of four different types of partly configurable products, that are related to partial modularity and configurability, which reflect to company´s operative decisions and related business environment as described above. Thus, partly configurable products consist of mix of Module System, modules, and ETO elements. Types A.2, and C of partly configurable product also highlight the business´ aim with the ETO element, which ultimately shall or shall not follow product´s rules and restrictions. These findings suggest that even if a business is aiming for product-centricity over project-centricity with such partly configurable capital goods, gaining competitive advantages through product development and subsequent delivery is constrained, and affected by operative decisions by the business. Businesses delivering these types of goods within HVLV context may have challenges in gaining competitive edge as Module System is subject to frequent changes, and unique solution are allowed in the product. These findings also contribute to partly configurable product engineering' and management' practitioners in understanding the modularity and configurability of their product, in recognition that constraints do exist, and in recognition of operational decisions over the product, thus providing avenue for further development based on their operating business environment for increased competitiveness.

5 CONCLUSION

The publications selected in the exploratory review described and presented different approaches for products, such as mass customization (Juuti & Lehtonen, 2006), brownfield process for designing modular product families through reuse of existing assets that prompt product limitations (Pakkanen et al., 2015), Adaptive Generic Product Structure (AGPS) which is intended for managing product variety in ETO manufacturing through efficient reuse (Brière-Côté et al., 2010), and managing partly configurable modular systems through understanding of product development process through the order in which design decisions are made and understanding the dependencies of design elements (Pakkanen et al., 2021). However, with the reviewed publications a less emphasized area was defining types of partly configurable products, where competitiveness is increased by the ability to manage Module Systems and customer specific unique elements of the design.

6 LIMITATIONS

Aim of this paper was to answer what partly configurable products are, and to describe the key concepts and interrelation of those. This limited the possibility to provide chronological, or other, order in developing such products in detail. Additionally, the selected search criteria produced publications suitable to answer the question through the found descriptions and definitions, however it could be more prone to modular products´ definitions and their interrelations due to scarcity of literature over partly configurable products. The definitions themselves also have overlap at the conceptual level that is not addressed in deep. Literature also suggests modularity over other areas, such as product-service systems or software, which were not the focus of this paper.

7 FUTURE WORK

Partitioning logic considers business environment including suppliers and supply of products, and design reasoning path captures the essence of variation need. However, when partly configurable product is being defined and engineered for delivery, the found approaches undervalue the constraints which may originate from supply side of products. When considering business-to-business context of HVLV partly configurable capital goods, such as cruise vessels, the definition and engineering for delivery, and delivery of partly configurable products and projects provides an avenue for further research. Belkadi et al. (2016) proposed an approach in co-defining product structure and related production network, considering customer´s needs, modular product, and production system. This suggest the future research aim should be at interorganizational value co-creation with the three key organizational parties (suppliers, provider of products, and customers) in defining and engineering delivery, and delivering of the partly configurable industrial capital goods.

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