Integrating Sustainability Considerations into Product Variety and Portfolio Management

Khaled Medini, Thorsten Wuest, David Romero, Valérie Laforest

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 00 (2019) 000–000

www.elsevier.com/locate/procedia

53rd CIRP Conference on Manufacturing Systems

Integrating Sustainability Considerations into Product Variety and Portfolio Management

Khaled Medini[a], Thorsten Wuest[b], David Romero[c], Valérie Laforest[d]

[a]Mines Saint-Etienne, Univ Clermont Auvergne, CNRS, UMR 6158 LIMOS, Institut Henri Fayol, 42023 Saint- Etienne, France
[b]Industrial and Management Systems Engineering, West Virginia University, Morgantown, WV 26505, USA
[c]Tecnológico de Monterrey, 14380 Mexico City, Mexico
[d]Mines Saint-Etienne, Univ de Lyon, CNRS, UMR 5600 EVS, Institut Henri Fayol, 42023 Saint- Etienne, France

* Corresponding author. Tel.: +33 4 77 42 93 17; fax: +33 4 77 42 66 33. *E-mail address:* khaled.medini@emse.fr

Abstract

Customers today desire more individualized products and services. As a consequence, the market must deal with a significant increase in a variety of offerings to satisfy this changing customer demands. This rapidly increasing variety affects operations complexity of manufacturers and subsequently costs and environmental impact. Consequently, companies need to better understand and find innovative ways to unleash a variety of benefits as well as driving down costs and environmental impacts. This paper reports on a research conducted within the Thomas Jefferson project SUSTAIN aiming to innovatively integrate environmental sustainability in practitioners' decisions, on a win-win basis. More specifically, a general framework is shaped in a view to support the integration of sustainability considerations into the management of product variety and portfolio. The framework development relies on variety and portfolio management, and product configurators. Relevant background literature has been analyzed and the framework is described and discussed.

Keywords: Product Variety Management; Portfolio Management; Configurators; Sustainability; Mass Customization; Ramp-up.

1. Introduction

Companies are challenged by increasingly individualized customer demands calling for higher offering variety while at the same time aiming to meet sustainability requirements [1]. However, offering a wider spectrum of choices to the customer implies higher complexity in managing the operations ranging from product or service design up to end-of-life treatment. *Variety management,* as a means to control product and service range and manage the resulting-effects, plays a major role in maximizing both customer and company value in a high variety production context [2]. The idea of continuously controlling product and service range is consistent with the operational objectives of "portfolio management". Cooper et al. [3] define *portfolio management* as a dynamic decision process whereby a business' list of active new products and R&D projects are constantly updated and evaluated. In this sense, the synergies between *variety* and *portfolio management* align perfectly with the objective of supporting companies operating in high variety production environments. While *variety management* has the potential to moderate and mitigate variety-induced complexity at the operational level, *portfolio management* lends itself to medium- and long-term decisions and a company's strategy [2].

The focus of past research conducted in these domains was however limited mainly to the *economic perspective* from a company's point of view as well as to maximize value for the customer, putting aside "sustainability" considerations [1] [4]. The recent international reports/studies and summits focused on climate change and environmental issues put "sustainability" objectives at stake for companies, consumers, and governments. Subsequently, these considerations cannot be omitted without jeopardizing the market position anymore from the decision-making process in the industrial context. In this sense, recent works started to address the integration of "sustainability practices and approaches", such as *eco-design* into product portfolio and variety management [4] [5] [6]. However, there is still a distinct need for *operational frameworks* to integrate sustainability considerations into product variety and portfolio management [4].

This paper aims at outlining a general framework that is currently under development within the SUSTAIN project. The objective of the said framework is to support the seamless integration of sustainability considerations into product variety and portfolio management from a more holistic perspective.

The remainder of the paper is organized as follows: Section 2 provides an overview of the state-of-the-art in product variety and portfolio management, Section 3 introduces a "product and service configurator" as an option to address the customer demand for personalization while managing product variety, Section 4 presents the general research framework, and Section 5 provides perspectives into "product variety" and "portfolio management" considering sustainability. The paper ends with concluding remarks in Section 6.

2. Variety and Product Portfolio Management

In order to leverage the synergies between product variety management and portfolio management, this section reports on research that is covering the intersection of these areas or showing their complementarities.

Looking at tactical and operational levels, there are several worthwhile product variety management approaches reported during the past few decades. They gained more visibility within the "mass-customization" era [7] [8]. *Mass-customization* aims to meet individual customer needs with near mass-production efficiency [8]. Consistently with this idea, the basic principle of *variety management* is to meet customized demands in a cost-efficient way. This involves developing differentiated products or services by reusing and sharing assets as much as possible [2]. Subsequently, both modularity and commonality are seen as major drivers of product variety management. *Modular systems* consist of a set functionally and physically independent components referred to as modules. *Variety* is generated by combining those modules, leading to higher flexibility and lower time-to-market [2] [9] [10]. *Commonality* stems from the principle of 'not reinventing the wheel', and it aims to increase the rate of shared and standard resources.

Consistently with the above principles, concepts such as "product families" and "product platforms" have known an expansion throughout past decades in many industries such as automotive. Volkswagen's 'Laengs & Querbaukasten' are a prime example of this strategy leading to a significant reduction of different parts across models. *Product family* refers to a grouping of similar variants into families. A *product platform* represents a collection of parts and product variants shared by product families [2] [3]. Leveraging product platforms across different segments and/or market niches allow for higher economies-of-scope. Among the techniques in this area, one could state clustering, design structure matrices, and data mining [9] [11] [12]. Recent research started to integrate a profit perspective in product variety management, i.e., consider not only costs [13] [14] but also sales revenue associated with variants [10] [14]. Beyond empirical research, other approaches with mentioning in this area include: "linear programming". The literature reports that *product variety management* drivers such as "modularity" and "commonality" [2], and models to reinforce these drivers while sustainability considerations are rarely addressed [5].

Variety management identifies and applies methods and tools to mitigate variety-induced complexity and to improve the range of offered products. In order to unleash the potential of overseeing product range at a more strategic level, efforts from variety management and product portfolio management should be joined. In fact, looking at the strategic level, authors such as Pinheiro et al. [4] argue that there is a lack of frameworks and tools within companies to guide decision-making towards more sustainable operations. While *portfolio management* is closely tied to company strategy, it relies on operational methods and tools to support and operationalize the decision-making process. Based on empirical research, a *general framework* defines the main "drivers" of product portfolio performance, namely formalization, methods, and integration [15]. In line with this research stream, a general framework integrating – *eco-design* – in product portfolio management was proposed by Pinheiro et al. [4]. This framework clearly delineates (i) guidelines, methods and tools, (ii) organization, and (iii) strategy as three pillars for integrating eco-design in portfolio management. It is assumed to provide decision-support for new product development. Referring to Pinheiro et al. [4], our research is clearly positioned in the guidelines, methods and tools pillar (P1). In this area, a comprehensive review was carried out by Cooper et al. [3] who identified several methods empirically analyzed. Based on the survey more than a third of each company use one of the following: (i) financial methods, (ii) business strategy methods, (iii) bubble diagrams, and/or (iv) scoring models. A fifth of the surveyed companies used (v) checklists. *Financial methods* include payback, net present value, and similar techniques. *Business strategy* methods derive project ranking based on the decided strategy. *Bubble diagrams* provide a visual representation of options according to different criteria (represented in X-Y axes). *Scoring models* use basically scoring systems to holistically evaluate options according to several criteria. *Checklists* refer generally to lists of yes/no questions.

3. Product/Service Configurators

Product configurators allow sharing product alternatives or variants with the customer in a scalable way to ease and automate sales and to some extent production planning and production itself. A *configurator* is defined as a knowledge-based system that supports the user in creating personalized products by specifying modules, functionalities, and/or capabilities [13] [16]. Previous studies argue that *product* *variety* and the number of customers are among the key factors underlying investment decision in configuration systems [16].

Generally, configurators can be developed from scratch or through applying software shells which involves buying software. The decision depends on factors such as cost and technical requirements [17] [18]. Major benefits of configurators reported on in literature relate to efficient order fulfilment and improved operational performance [16] [17].

Conversely, these benefits point to a limitation of existing literature regarding the scope of the current research, for instance, enabling a consistent "environmental" sustainability assessment of configured solutions. While "sustainability" and "configuration" have been used jointly in literature, only limited research deals specifically with product configurators [19] [20].

Since configurators are closely tied to the process of customer order fulfilment and particular to product or service quotation process [21] [22], the integration of "sustainability" considerations in the quotation process is required for a holistic representation of the product variants impact and an informed decision by the customer. Typically, the quotation process addresses the price of the product, derived from cost data and configuration data. However, extending the scope of the quotation entails several challenges such as data scarcity for environmental assessment and meaningfulness of (key) indicators to non-expert customers.

Therefore, *environmental indicators* must fulfil certain requirements to be considered for inclusion in product/service configurators. The environmental indicators should be ideally factual, unbiased, and measurable as a base requirement. Factual and unbiased are crucial requirements to be accepted by a wide variety of customers across the political and educational spectrum. Including indicators that are related to certain viewpoints bear the risk of creating a negative impact on the company especially in the days of 'fake news' and social media. Measurable is more of a technical requirement even though there are overlaps with the previous two. The environmental impact needs to be quantifiable reliably to provide the input for the configurator to subsequently provide an automated response to the interested customer. Besides these base requirements, there are several other high-level requirements, such as the significance of the indicator to the decision-making process. These higher-level indicators are often difficult to measure at the company, product, or industry entity-level in specific.

4. General Research Framework

The previous analysis and discussion inform the development of a "general framework". This *framework* provides the foundation of the research to address the integration of sustainability considerations in product variety and portfolio management. Figure 1 shows the basic components of the proposed framework as well as typical interactions among them. The product/service configurator is understood to be the central component that allows capturing the customers' requirements based on product/service configurations directly as the customers are building and choosing their preferences. Additionally, it allows capturing the said customer preferences regarding the sustainability criteria based on the indicators' weights. Configuration and quotation data are derived from the data exchange with the *product family data repository* and *product/service portfolio* data components. This architecture is consistent with a three-step-process to maintain the whole system operation. The process involves capturing the customer requirements, maintaining/updating the configurator data and managing the quotation process, and managing the product/ service portfolio (see Fig. 1).

- *Capturing Customer Requirements* – This step is enabled by a smooth configuration process allowing a given customer to easily select required options of a given product or service. This is referred to also by choice navigation is seen as a basic capability in the mass- customization domain [23]. The prerequisite of this process is a clear definition of the space of possible solutions to meet customer expectations. The second pillar of this step is capturing customer preference regarding economic and environmental perspectives of the configured solution. An efficient and easy-to-apply means are multi-criteria decision-making techniques which allow deriving weights of the indicators based on customer judgement [24].
- *Maintaining/Updating the Configurator Data and Manage the Quotation Process* – The embedded data within the configurator needs to be continuously updated, e.g. upon introducing a new product/service variant, changing the bill-of-material of some variants, etc. Similarly, the quotation process needs to be regularly updated based on available data about the product/service family including its bill-of-material, process, suppliers, cost data, and material data. This allows deriving both cost and price information and environmental impact evaluation. Assuming the pricing depends heavily on the aggregate product/service cost, the economic perspective can be effectively covered. In contrast, calculating environmental indicators is more challenging due to the huge amount of data required for an effective assessment and to the complex choice of relevant indicators depending on assessment objectives and system boundaries. For this reason, only a subset of environmental indicators will be selected according to criteria such as factuality, measurability, and significance for decision-making [25].
- *Managing the Product/Service Portfolio and its Variety* – This step remains at the heart of the process of integrating sustainability considerations in the product portfolio and variety management. In fact, this step spans over strategic and tactical planning levels which have a great impact on the firm economic and environmental performance. In order to manage the product portfolio, several models can be used as reported in Cooper et al. [3]. In the specific context of the current project, both economic and environmental sustainability perspectives should be considered. *Economic sustainability assessment* is supported by cost modelling and estimation techniques [15] [26] [27]. This provides a basis for further analysis using lightweight financial models such as payback and

return on investment [3] [15]. *Environmental sustainability evaluation* relies on the availability of a "lightweight lifecycle inventory" to effectively manage this information. Looking at the standard *Life Cycle Analysis (LCA) framework,* environmental criteria could involve, for example, the amount of waste generated, energy consumption, water consumption, etc. In order to deal with the objectives' heterogeneity, multi-criteria decision-making is needed to mitigate the complexity of the decision-making process on the "product portfolio management" considering heterogeneous criteria, for instance, environmental and economic. *Variety management* is fostered through the "modularization" of the product/service architecture and the enhancement of components standardization as much as possible. "Clustering" and "System Engineering" are the drivers of this activity [9].

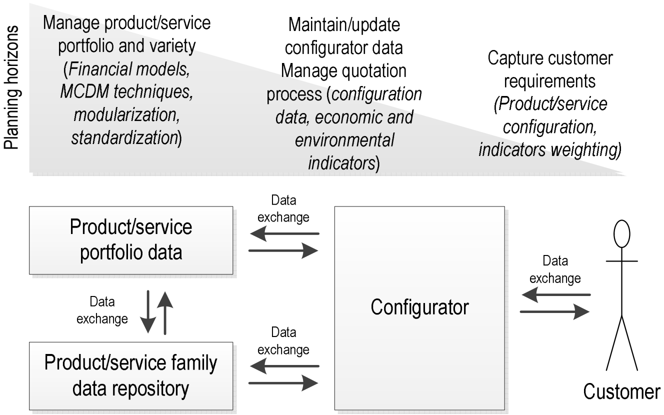

Fig. 1. General Research Framework

5. Discussion and Ongoing Research

While various frameworks for sustainability assessment are available abundantly [29], the significance of "sustainability" to the decision-makers is often driven by their personal (environmental) consciousness, preferences, and/or (green) marketing purposes. Framing a strategy that truly incorporates "sustainability" as an equal pillar in business development is still a rare practice [30]. Recent endeavors started to focus on integrating "sustainability" with other "customer-oriented" strategies as an attempt to ultimately integrate sustainability stakes in the business realm. Examples include EU projects within the FP7 program (e.g. *S-MC-S – Sustainable Mass Customization – Mass Customization for Sustainability*) and the H2020 program with the *Environment & Climate Action.* The SUSTAIN project funded by *Thomas Jefferson Fund* lends itself in this continuum. The originality of the proposed framework presented within this paper lies in integrating sustainability in an attempt to create a win-win set-up for the company and the customer, and ultimately the society. In fact, consistent with the customer-driven business philosophy, the management of product/service variety and portfolio management are driven by the customers. More specifically, economic and environmental assessments of a given product or service configuration are enabled by configurators upon collecting customer preferences and then used them to make mid- and long-term decisions on which product/service variants to reinforce and which ones to limit or even eliminate. In this way, the risk for the firm is mitigated as the approach to pursue sustainability is "market-driven". Consequently, this set-up is designed to generate higher revenues depending on the customers' sensibility to environmental sustainability.

The proposed framework presented in this paper creates a pathway to meet the above objectives. However, such pathway still entails several technical and market challenges that need to be addressed. For example, *product components reusability* to capture repetitions in design and manufacturing in order lower costs and increase production efficiency; *product platforms* as the basis for customization, variety management, and customer-centricity; *process(es) platforms* for providing a "customizability analysis" in design for sustainable mass-customization where customers preferences are evaluated and optimized with different design alternatives; and *integrated product lifecycle management* facilitating quick responsiveness to the changes in customers preferences [31].

Therefore, ongoing research involves the refinement of conceptual and technical integration of the guidelines and methods for capturing the customer requirements, managing the quotation process, and managing the product/service variety and product portfolio. Additionally, while the scope of the framework is concerned with the discrete manufacturing sector, a candidate set of specific activities will be selected to narrow the scope and direct the development of the framework towards more specific contexts.

6. Conclusion

The evolution towards sustainable (green) production and consumption modes shaped the research in many fields with the aim to help firms adapt their offers and their operation to these trends. For instance, individualized customer demands and sustainability pressure for product designs and production systems has motivated a research stream dealing with mass-customization and high-variety production on the one hand side and sustainability on the other hand. Industry 4.0 paradigm recognizes the importance of both these areas. The presented work integrates these two streams in the form of proposing a first iteration of a market-oriented framework with these two key pillars reflecting the future of industry development. The proposed research framework provides methods and tools for promoting sustainable and customized solutions in both B2B and B2C set-ups.

Acknowledgements

This work is supported by the Thomas Jefferson Fund project SUSTAIN.

References

[1] Stock, T., Seliger, G. Opportunities of sustainable manufacturing in Industry 4.0. Procedia CIRP 2016; 40:536–541.
[2] ElMaraghy, H., Schuh, G., Elmaraghy, W., Piller, F., Schönsleben, P., Tseng, M., Bernard, A.. Product variety

management. CIRP Ann. - Manuf. Technol. 2013; 62:629–652.
[3] Cooper, R.G., Edgett, S.J., Kleinschmidt, E.J. New product portfolio management: Practices and performance. IEEE Eng. Manag. Rev. 2000; 28:13–29.
[4] Pinheiro, P., Jugend, M.A., Demattê Filho, D., Armellini, F., L.C. Framework proposal for ecodesign integration on product portfolio management. J. Clean. Prod. 2018; 185:176–186.
[5] Medini, K., Boucher, X. An approach for steering products and services offering variety towards economic and environmental sustainability. CIRP J. Manuf. Sci. Technol. 2016; 15:65–73.
[6] Zvezdov, D., Hack, S. Carbon footprinting of large product portfolios. Extending the use of ERP systems to carbon information management. J. Clean. Prod. 2016; 135:1267–1275.
[7] Piller, F., Kumar, A. Mass customization: Providing custom products and services with mass production efficiency. Capco Inst. J. Financ. Transform. 2006; 18:125–131.
[8] Pine, B.J., 1993. Mass customizing products and services. Plan. Rev. 1993; 21:6–55.
[9] Ezzat, O., Medini, K., Boucher, X., Delorme, X. Product and service modularization for variety management, In: Procedia Manufacturing. 2019; 148–153.
[10] Medini, K. Modularity and variety spinoffs: A supply chain planning perspective. Int. J. Ind. Eng. Theory Appl. Pract. 2015; 22:753-768.
[11] Hochdörffer, J., Laule, C., Lanza, G. Product variety management using data-mining methods - Reducing planning complexity by applying clustering analysis on product portfolios. IEEE Int. Conf. Ind. Eng. Manag. 2018; 593–597.
[12] Sun, J., Chai, N., Pi, G., Zhang, Z., Fan, B. Modularization of product service system based on functional requirements. Procedia CIRP 2017; 64:301–305.
[13] Hvam, L., Kristjansdottir, K., Shafiee, S., Mortensen, N.H., Herbert-Hansen, Z.N.L. The impact of applying product-modelling techniques in configurator projects. Int. J. Prod. Res. 2018; 7543:1–16.
[14] Chiu, M.C., Okudan, G. An Investigation on the impact of product modularity level on supply chain performance metrics: An industrial case study. J. Intell. Manuf. 2014; 25:129–145.
[15] Jugend, D., Luis, S., Henrique, M., Augusto, P., Miguel, C. Product portfolio management and performance: Evidence from a survey of innovative Brazilian companies. J. Bus. Res. 2016; 69:5095–5100.
[16] Shafiee, S., Felfernig, A., Hvam, L., Piroozfar, P., Forza, C. Cost benefit analysis in product configuration systems. CEUR Workshop Proc. 2018; 2220:37–40.
[17] Forza, C., Salvador, F. Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems. Int. J. Prod. Econ. 2002; 76:87–98.
[18] Haug, A., Hvam, L., Mortensen, N.H. Definition and evaluation of product configurator development strategies. Comput. Ind. 2012; 63:471–481.
[19] Hankammer, S., Hora, M., Canetta, L., Sel, S.K. User-Interface Design for Individualization Services to Enhance Sustainable Consumption and Production. Procedia CIRP 2016; 47:448–453.
[20] Skjelstad, L., Thomassen, M. Integrating Sustainability Knowledge In Choice Navigation, 2018; 8–15.
[21] Hvam, L., Pape, S., Nielsen, M.K. Improving the quotation process with product configuration. Comput. Ind. 2006; 57:607–621.
[22] Zhang, L.L., Lee, C.K.M., Xu, Q. Towards product customization: An integrated order fulfillment system. Comput. Ind. 2010; 61:213–222.
[23] Salvador, F., de Holan, P.M., Piller, F.T. Cracking the Code of Mass Customization. MIT Sloan Manag. Rev. 2009; 50:71–78.
[24] Medini, K., Da Cunha, C., Bernard, A. Tailoring performance evaluation to specific industrial contexts - Application to sustainable mass customisation enterprises. Int. J. Prod. Res. 2015;53:2439–2456.
[25] Medini, K., Bettoni, A., Fontana, A., Corti, D., Zebardast, M., S-MC-S – D3.1 Assessment Model. European Commission 2001; 503.
[25] Medini, K., Boucher, X., Peillon, S., Vaillant, H. Economic assessment of PSS value networks – an algorithmic approach. IFIP Adv. Inf. Commun. Technol. 2018; 535:141–149.
[26] Rush, C., Roy, R. Analysis of cost estimating processes used within a concurrent engineering environment throughout a product life cycle. 7th ISPE Int. Conf. Concurr. Eng. Res. Appl. 2000; 44:58–67.
[27] Xu, Y., Elgh, F., Erkoyuncu, J.A., Bankole, O., Goh, Y., Cheung, W.M., Baguley, P., Wang, Q., Arundachawat, P., Shehab, E., Newnes, L., Roy, R. Cost engineering for manufacturing: Current and future research. Int. J. Comput. Integr. Manuf. 2012; 25:300–314.
[29] Angelakoglou, K., Gaidajis, G. A review of methods contributing to the assessment of the environmental sustainability of industrial systems. J. Clean. Prod. 2015; 108:725–747.
[30] Bolis, I., Morioka, S.N., Sznelwar, L.I. Are we making decisions in a sustainable way? A comprehensive literature review about rationalities for sustainable development. J. Clean. Prod. 2017; 145:310–322.
[31] Osorio, J., Romero, D., Betancur, M.C., Molina, A. Design for sustainable mass-customization: Design guidelines for sustainable mass-customized products. 20th Int. ICE Conf. 2014.