Scenario-based Portfolio Management

Modelling Future Cost and Effect on Manufacturing

Nielsen, Morten Skogstad; Brunø, Thomas Ditlev; Andersen, Ann-Louise; Nielsen, Kjeld

Published in:
Procedia CIRP

DOI (link to publication from Publisher):
10.1016/j.procir.2022.05.183

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 107 (2022) 1509–1514

www.elsevier.com/locate/procedia

55th CIRP Conference on Manufacturing Systems

Scenario-based Portfolio Management: Modelling Future Cost and Effect on Manufacturing

Morten Skogstad Nielsen[a]*, Thomas Ditlev Brunoe[a], Ann-Louise Andersen[a], Kjeld Nielsen[a]

[a]Departmen of Materials and Production, Aalborg University, Fibigerstraede 16, 9220 Aalborg, Denmark

* Corresponding author. Tel.: + 45 28103250; *E-mail address:* Mortensn@mp.aau.dk

Abstract

As a response to the increased demand for more customized products at a lower cost and with shorter lead times, many of today's manufacturing companies have embarked on the journey of modularization in either their product portfolio, their manufacturing setup or in both. However, transitioning towards a modular setup generates uncertainties on where and what to modularize, as well as on the consequence. Some of these questions can be answered and clarified through the use of data models, making it possible to create and test different architectural scenarios and thereby make decisions based on actual data rather than best guess and tacit knowledge. In order to get access to actual ERP data and be able to test and validate the method in a real life environment, this research is made in collaboration with a large manufacturing company using the design science methodology. The purpose of this research is to present an approach for creating a data model based on standard ERP data that will allow engineers and system architects to create strategic architectural scenarios and evaluate these in terms of expected savings, impact on manufacturing and other relevant parameters.

Peer-review under responsibility of the International Programme committee of the 55th CIRP Conference on Manufacturing Systems

Keywords: Modularization; Portfolio Management; Scenario; Modelling;

1. Introduction

Manufacturing companies are faced with the wicked problem of having to serve markets with an increasing amount of product variants, while still being able to produce at a cost similar to mass production [1, 2]. In response, many manufacturing companies have introduced modular product architectures allowing them to make rapid and more frequent changes in their product portfolio in order to follow markets more closely [3, 4]. Identifying and selecting which new variants should be added to the product portfolio is carried out through portfolio management. Portfolio management is traditionally referred to as a dynamic decision process where the right (product) development projects must be selected to continually update the list of active products served to given market [5]. This portfolio management process consequently has a huge impact on manufacturing. Nevertheless, it can be difficult to predict and consider the impact of the portfolio management process on the manufacturing setup [5-8]. As new product variants are often a result of incremental product development and the use of modular development allows for decupled development in the product architecture, information on the already existing product portfolio and the resulting manufacturing setup contain valuable information that can be used when determining the future product portfolio. Therefore, the purpose of this research is to demonstrate how it is possible create a data model, based on ERP data, that represents the product portfolio and makes it possible to conduct hypothetical changes to the product architectures for a given part of the product portfolio in order to calculate new cost and effects on the manufacturing environment. The remainder of this paper is structured as follows: Section 2 presents the related research while section 3 describes the research methodology. Section 4 presents the ontology and data model used. Section 5 presents

Peer-review under responsibility of the International Programme committee of the 55th CIRP Conference on Manufacturing Systems
10.1016/j.procir.2022.05.183

an example from a case company, while Section 6 presents the discussion and Section 7 conclusively summarizes the contribution and future research directions.

2. Related Research

As this research focuses on managing a portfolio of modular product architectures and how ERP data can be used to model future cost and effect on manufacturing based on scenarios, related research on modular product architectures, portfolio management, and new product introductions impact on manufacturing is reviewed in the following section. The concepts of modular product architectures and modularity have been applied in manufacturing companies for a long time in order to introduce a high number of product variants, while still gaining the benefits of economies-of-scale [9-14]. These modular product architectures, also known as ‘product platforms’, have been defined in different ways mostly focusing on reusability and commonality, e.g., as a ‘collection of assets shared by a set of products’ [15] or as a ‘set of common components, modules, or parts from which a stream of derivate products can be efficiently develop and launched’ [16]. Two main enablers of modularization include interface management and strategic partitioning, where system elements are divided into variant drivers and non-variant drivers [17, 18]. Portfolio management is defined as a dynamic decision process, whereby a business´s list of active new product (and R&D) projects is constantly up-dated and revised [19]. *Cooper et al.* classifies various types of portfolio management methodologies such as; financial, business strategy, portfolio maps and, scoring models. The difference in these are the design of the portfolio management process and by which parameters the selection of development projects are made. With the financial perspective it is the profitability and productivity that is in focus with metrics such as; NPV, RONA and, ROI [20, 21]. Whereas in the strategic approach, one method could be to allocate resources into strategic buckets where the different projects are placed within these buckets and ranked [22-24]. To manage interfaces within a specific product architecture or across an entire portfolio of product architectures, a management process must be established. First, the current state of available interfaces must be identified and secondly, these must be evaluated based on multiple parameters to set the future direction for which to reuse, which to discard, and which to develop [25]. This process could be argued to be very similar to the various types of portfolio management methods as described by Cooper *et al.* [5]. However, while the portfolio management process aims at creating a balance between projects that yield a breakthrough and significant competitive advantages with projects having a high likelihood of success [5], the interface management process aims at high standardization and reuse of interfaces across the entire portfolio. The integration of research and development (R&D) and manufacturing has long been documented [6, 7, 26, 27], however, problems often arise because of interdepartmental differences [7, 28]. Therefore, the research objective is to demonstrate how to create a data model, based on ERP data, that represents the product portfolio and makes it possible to conduct hypothetical changes to the product architectures for a given part of the product portfolio in order to calculate new cost and effects on the manufacturing environment.

3. Research Methodology

To address the aforementioned research objective, this research is made as design science research in collaboration with a large scale manufacturing company. Design science research is used due to its focus on developing innovative artefacts to be used in applications domains e.g. organizations, people, or systems [29, 30]. When using design science, seven guidelines are important. The first three guidelines are concerned with designing an artifact based on a relevant problem and being able to evaluate this in the right environment. Therefore this research is made in collaboration with a manufacturing company, ensuring the resulting artifact is grounded in a real problem identified in collaboration with experts. Hereafter the resulting artifact is evaluated with the experts in the context of the manufacturing company. The two following guidelines are concerned with research rigor and contribution which has been achieved through a literature review of related work and the use of UML classes and objects in the description of the artifact for verification. The final guidelines revolve around the design process and communication of the research which is achieved through the use of circular feed back loops between the researcher and experts from the manufacturing company in which the artifact was developed and continuously evaluated.

4. Ontology and Data Model

The proposed approach to model ERP master data to create a data model in which it is possible to create and test different architectural scenarios is based on a company specific ontology used in the case company. Table 1 displays the data tables used along with a short description and fig. 1 displays how the tables are modeled together in a UML class diagram.

Table 1. Data tables used in the data model.

Table name	Description
Material Master	List of unique materials in the model (both products and components, and internally produced vs. externally purchased)
Cost	A list of all materials in material master and their respective cost
Production As-Is	A list of what has been produced of all the materials. Where and in what volume
Production Forecast	A list of what is expected to be produced of all the materials
Purchasing As-Is	A list of materials that have been external purchased and in what volume
Purchasing Forecast	A list of what is expected to be purchased external and in what volume
Portfolio As-Is	All BOM full exploded for materials in scope with additional information e.g. classification of components
Portfolio Senario	A copy of portfolio architecture with the changes made by system experts

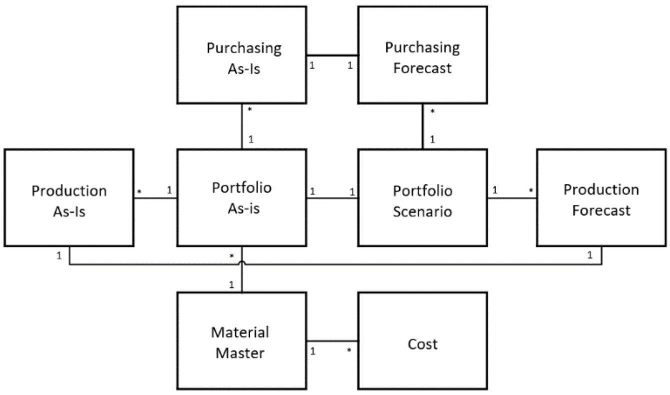

Fig. 1. UML Class diagram describing the data model and relationship between the different data tables.

The portfolio tables described in table 1 and displayed in table 2 and fig. 2 are the main tables in this model. These tables are created specific for this purpose an contain all the products arranged in different combinations through bill of materials (BOM) so that it is possible to see which components constitutes a product. Furthermore, this table has been enriched with interface information as described by Skogstad et al. [25]. Starting from the left column in table 2, '*BOM NR*' represents a unique BOM. Each product can have multiple BOM´s if e.g. the same product is produced in multiple factories. '*Product*' is the representation of the actual architecture/ product. '*Component*' is all the elements that makes up the product. '*Usage*' is the number of components required in the product. '*Type*' is a classification of the components used to identify similar components with same "form-fit-function". '*Interface A/B*' based on Skogstad [25] display that there is an interface between component type A and B and because the numeric values are similar in product 1001 and 1002 it can be seen that they share similar interface between component types A and B. In column '*Interface C/D*' it can be seen that because product 1001 and 1002 do not have same numeric value they do not share similar interface between component type C and D.

BOM NR	Product	Component	Usage	Type	Interface A/B	Interface C/D	Interface B/D
XXXX	1001	2001	1	A	1		
XXXX	1001	2002	2	B	1		1
XXXX	1001	2003	1	C		1	
XXXX	1001	2004	1	D		1	1
YYYY	1002	2001	1	A	1		
YYYY	1002	2005	2	B	1		1
YYYY	1002	2006	1	C		2	
YYYY	1002	2007	1	D		2	1

Table 2. Example of portfolio table

This table containing portfolio information can also be described using a block diagram containing the same information. In fig. 2 the information described in table 2 is displayed using a block diagram for understanding purpose, this is however not possible for the whole model as this could contain data from thousands of products.

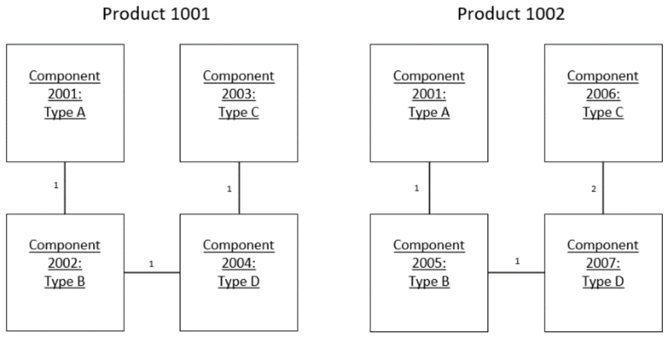

Fig. 2. UML object displaying information from portfolio table

When data is modeled as displayed in fig. 1 it is possible to retrieve multiple pieces of information by combining the different data sets. One of the options is to calculate all variable cost (Cost of Goods Sold) associated with producing the entire portfolio. This is possible because the cost for each component is available in the cost table and can be added to the portfolio table creating each distinct BOM with cost. The sum of all components constitutes the cost of the product, and because the amount of products produced in a given time period is available in the production As-Is, it is possible to summarize these to see what the related cost have been in that given time period. Another option is to see how many unique components have been used to produce the current portfolio and where these have been either produced or purchased and in which quantity. All components can be grouped based on material type to see where in the architecture the most variance and cost are created. A third option is to identify the number of unique interfaces between each component and "backtrack" these to firstly see how many unique products use this specific interface and in what volume and at what cost are these produced. This makes it possible to compare specific interfaces based on volume and cost. Once this information is made available to the engineers and system architects, it is possible to make informed decisions about where to modularization and standardization, which will be further explained in the following example.

5. Example

When engineers and system experts are to use the model for identifying potential scenarios, there are several ways to take an offset for creating different scenarios. One scenario could be to keep all the different interfaces that exist in the current portfolio and only use best-of-breed within one material type that have the same interfaces. Another scenario could be that system experts know that there is no customer requirement or physical hindering for standardizing specific interface variants if e.g., system 1001 and 1002 could share interface between material type C and D. A third scenario could be to do a combination of the previous scenarios.

5.1. Current setup

For explanation and benchmarking purpose, the portfolio contains four products which are produced in the volume displayed in table 5.

BOM NR	Product	Component	Usage	Type	Cost	Interface A/B	Interface C/D	Interface B/D
XXXX	1001	2001	1	A	€ 10,00	1		
XXXX	1001	2002	2	B	€ 8,00	1		1
XXXX	1001	2003	1	C	€ 4,00		1	
XXXX	1001	2004	1	D	€ 6,00		1	1
YYYY	1002	2001	1	A	€ 10,00	1		
YYYY	1002	2005	2	B	€ 7,00	1		1
YYYY	1002	2006	1	C	€ 3,00		2	
YYYY	1002	2007	1	D	€ 12,00		2	1
ZZZZ	1003	2001	1	A	€ 10,00	1		
ZZZZ	1003	2008	2	B	€ 14,00	1		1
ZZZZ	1003	2009	1	C	€ 4,00		2	
ZZZZ	1003	2007	1	D	€ 12,00		2	1
NNNN	1004	2001	1	A	€ 10,00	1		
NNNN	1004	2010	2	B	€ 12,00	1		1
NNNN	1004	2006	1	C	€ 3,00		2	
NNNN	1004	2007	1	D	€ 12,00		2	1

Table 3. The portfolio table in the current setup with cost data displayed for each system element

Now that the cost of system element and the number of produced units is known, it is possible to show how the costs are distributed across the different material types and also in which material type variance is created as displayed in fig. 3.

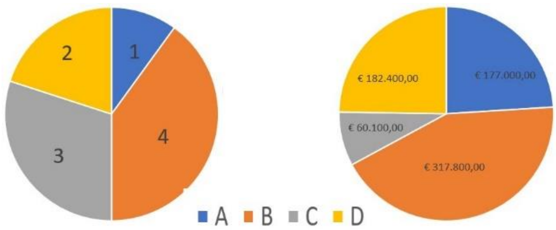

Fig. 3. Displaying how variance and cost are distributed based on material types in the current portfolio setup.

Because the volume of each component used in each product and the number of products produced are known, it is also possible to show the usage of each component in the current portfolio setup separated by which are made in house or purchased from supplier. This is displayed in table 4.

Component	Type	Usage	Make/Buy
2001	A	17700	Make
2002	B	10000	Buy
2003	C	5000	Buy
2004	D	5000	Make
2005	B	15000	Make
2006	C	10700	Buy
2007	D	12700	Make
2008	B	4000	Make
2009	C	2000	Buy
2010	B	6400	Make

Table 4. Table displaying the number of unique components and the usage of each of these in the current portfolio setup.

Furthermore, it is possible to calculate the cost related to producing the current portfolio setup in the volume that was produced within a given time period. This is done by summarising the cost of all components in each product and multiplying these with the units produced as displayed in table 5.

Product	Cost pr unit	Unit produced	Overall cost
1001	€ 36	5000	180.000
1002	€ 39	7500	292.500
1003	€ 54	2000	108.000
1004	€ 49	3200	156.800
			737.300

Table 5. Table displaying the cost of individual product and overall cost based on the current portfolio setup.

Now that these key figures have been found and calculated, these are to act as a benchmark for the scenario made by engineers and system architects.

5.2. Scenario

In this example to demonstrate the model, a scenario will be made to see what the effects would be if all interfaces where maintained in the portfolio, but best practice (lowest cost) for each material type is used under the constraint that all interfaces remain stable. Meaning that a components can only be changed to a component with similar interfaces. With a large portfolio, engineers and system architects would start looking at fig. 3 and it would be clear that the starting point would be material type B. This is because this is where the most variance is found and it is the largest cost driver in the portfolio. Because of the simplicity in the example, all material types will be investigated at the same time. First, the portfolio scenario table will be opened and this time it will be grouped according to material type as displayed in table 6.

BOM NR	product	Component	Usage	Type	Cost	Interface A/B	Interface C/D	Interface B/D
XXXX	1001	2001	1	A	€ 10,00	1		
YYYY	1002	2001	1	A	€ 10,00	1		
ZZZZ	1003	2001	1	A	€ 10,00	1		
NNNN	1004	2001	1	A	€ 10,00	1		
XXXX	1001	2002	2	B	€ 8,00	1		1
YYYY	1002	2005	2	B	€ 7,00	1		1
ZZZZ	1003	2008	2	B	€ 14,00	1		1
NNNN	1004	2010	2	B	€ 12,00	1		1
XXXX	1001	2003	1	C	€ 4,00		1	
YYYY	1002	2006	1	C	€ 3,00		2	
ZZZZ	1003	2009	1	C	€ 4,00		2	
NNNN	1004	2006	1	C	€ 3,00		2	
XXXX	1001	2004	1	D	€ 6,00		1	1
YYYY	1002	2007	1	D	€ 12,00		2	1
ZZZZ	1003	2007	1	D	€ 12,00		2	1
NNNN	1004	2007	1	D	€ 12,00		2	1

Table 6. Table portfolio scenario ordered according to material type

Now it is possible for engineers and system architects to make an informed discussion on the amount of variance that is required within each material type. e.g., from table 6 it can be seen that there are four different types of components with the type B and that these system elements have interfaces to system elements A and D. However, these interfaces have identical numeric value, meaning that they are similar and it is possible to interchange between the four existing components. Therefore, it is decided in this scenario to reuse component 2005 in all four products as this has the lowest cost. With material type C there is a difference in which interface these components uses when interfacing with system element D and as the overall scenario was to keep all interfaces it is only possible to use the one with the lowest cost with similar interfaces. Therefore, component 2003 will continue to be used in product 1001, but in product 1003 component 2009 will be replaced with component 2006 as this has a lower cost with similar interfaces. Similarly in material type D there is two different interfaces between material type C and D and therefore two system elements will remain.

5.3. Scenario evaluation

Having made the changes described in subsection 5.2 it is possible to show the resulting cost and the effect these changes will have to manufacturing. In this scenario the portfolio will be as displayed in table 7.

BOM NR	Mat (Syste	Mat (Sys Elem	Usage	Mat type	Cost	Interface A/B	Interface C/D	Interface B/D
XXXX	1001	2001	1	A	€ 10,00	1		
XXXX	1001	2005	2	B	€ 7,00	1		1
XXXX	1001	2003	1	C	€ 4,00		1	
XXXX	1001	2004	1	D	€ 6,00		1	1
YYYY	1002	2001	1	A	€ 10,00	1		
YYYY	1002	2005	2	B	€ 7,00	1		1
YYYY	1002	2006	1	C	€ 3,00		2	
YYYY	1002	2007	1	D	€ 12,00		2	1
ZZZZ	1003	2001	1	A	€ 10,00	1		
ZZZZ	1003	2005	2	B	€ 7,00	1		1
ZZZZ	1003	2006	1	C	€ 3,00		2	
ZZZZ	1003	2007	1	D	€ 12,00		2	1
NNNN	1004	2001	1	A	€ 10,00	1		
NNNN	1004	2005	2	B	€ 7,00	1		1
NNNN	1004	2006	1	C	€ 3,00		2	
NNNN	1004	2007	1	D	€ 12,00		2	1

Table 7. Portfolio scenario table after changes have been made

Looking at the portfolio scenario table it might not be easily visual what changes have been made, but when looking at table 8 displaying the cost of the individual systems and the overall cost of producing these, there is a great difference.

Product	Cost pr unit	Unit produced	Overall cost
1001	€ 34	5000	€ 170.000
1002	€ 39	7500	€ 292.500
1003	€ 39	2000	€ 78.000
1004	€ 39	3200	€ 124.800
			€ 665.300

Table 8. Table displaying the cost of individual system and overall cost based on the scenario made.

Comparing the sum of the overall cost from table 5 and 8, the model stipulates a cost savings close to 10% (approx. €72.000 in this example). Furthermore, is it possible to see the effect in manufacturing or supplier by knowing which components are either increasing or decreasing in usage and in which volumes as shown in table 9.

Component	Mat type	Usage	Difference	Make/Buy
2001	A	17700	0	Make
2002	B	0	-10000	Buy
2003	C	5000	0	Buy
2004	D	5000	0	Make
2005	B	35400	20400	Make
2006	C	12700	2000	Buy
2007	D	12700	0	Make
2008	B	0	-4000	Make
2009	C	0	-2000	Buy
2010	B	0	-6400	Make

Table 9. Table displaying new usage of components

6. Discussion

Because this research is made using design science research in collaboration with a case company the applicability and usability of this specific model is limited. However, because this model is built only on standard ERP data, it is argued that this research could be used as a generic example and the applicability and usability of this model could be used in another context. Most of the literature on the subject are revolving around the design processes where Bruch and Bellgran [31] concludes that some of the main challenges in creating integrated portfolios are information management as information about both the current and future portfolios are necessary. However, creating and maintaining a model like the one proposed in this research would help in the future portfolio management process, as it can calculate the implications and thereby assist in making more precise business cases when selecting future development projects. Therefore it is argued that this method is not only useful when pruning the portfolio but it could serve as a support tool in the traditional portfolio management process.

7. Conclusion

In this research, a new approach was presented that enables the creation of a model that allow portfolio managers, engineers and system architects to create and validate different architectural scenarios. Implementing and maintaining a model of a company's portfolio like the one presented in this research can have major implications as it would give the ability to create scenarios that can be validated and compared to find the most optimal solution. To utilize this approach, a database would need to be developed and parts of the company specific ERP system would need to be replicated and modelled in this. Future research extending on what is presented in this research could focus on several topics. Firstly, how could the model be expanded to contain more information about the architecture of the manufacturing domain. When conducting this research it was found that, in the company specific ERP system the data logic found in the product domain was replicated in the manufacturing domain. Secondly, what effect if any, would this approach have on the traditional portfolio management process and the organization as a hole. Further research could be made regarding the usability of this approach on co-development if more information regarding the manufacturing domain was made.

References

[1] Gilmore J. H., Pine B. J. Markets of one: creating customer-unique value through mass customization. Harvard Business Review Press; 2000.

[2] Baldwin C. Y., Clark K. B. Managing in an age of modularity. Managing in the modular age: Architectures, networks, and organizations, 2003; 149: 84-93.

[3] Ikeda M., Nakagawa Y. Two ways of modularization strategy in Japan: Toyota-Honda vs. Nissan-Mazda. documento presentado al noveno encuentro de la GERPISA, disponible en http://www.univ-evry.fr/labos/gerpisa, Paris, 2001;: 7-9.

[4] Ro Y. K., Liker J. K., Fixson S. K. Modularity as a strategy for supply chain coordination: The case of US auto. IEEE Transactions on Engineering Management, 2007; 54: 172-189.

[5] Cooper R. G., Edgett S. J., Kleinschmidt E. J. Portfolio management in new product development: Lessons from the leaders—I. Research-Technology Management, 1997; 40: 16-28.

[6] Adler P. S. Interdepartmental interdependence and coordination: The case of the design/manufacturing interface. Organization science, 1995; 6: 147-167.

[7] Lakemond N., Johansson G., Magnusson T., Safsten K. Interfaces between technology development, product development and production: critical factors and a conceptual model. International Journal of Technology Intelligence and Planning, 2007; 3: 317-330.

[8] Miguel P. A. C. Portfolio management and new product development implementation: A case study in a manufacturing firm. International Journal of Quality & Reliability Management, 2008;.

[9] Erens F., Verhulst K. Architectures for product families. Computers in Industry, 1997; 33: 165-178.

[10] Ericsson A., Erixon G. Controlling Design Variants: Modular Product Platforms. SME; 1999.

[11] Simpson T. W., Siddique Z., Jiao J. R. Platform-based product family development. In Product platform and product family design. Springer; 2006; 1-15.

[12] Huang G. Q., Simpson T. W., Pine II B. J. The power of product platforms in mass customisation. International Journal of Mass Customisation, 2005; 1: 1-13.

[13] Simpson T. W., Maier J. R., Mistree F. Product platform design: method and application. Research in engineering Design, 2001; 13: 2-22.

[14] Ulrich K., Eppinger S. D. Product design and development. McGraw-Hill; 2003.

[15] Robertson D., Ulrich K. Planning for product platforms. Sloan management review, 1998; 39.

[16] Meyer M. H. Revitalize your product lines through continuous platform renewal. Research Technology Management, 1997; 40: 17-28.

[17] Sanchez R. Creating modular platforms for strategic flexibility. Design Management Review, 2004; 15: 58-67.

[18] Sanchez R., Collins R. P. Competing—and learning—in modular markets. Long range planning, 2001; 34: 645-667.

[19] Cooper R. G., Edgett S. J., Kleinschmidt E. J. Portfolio Management for New Product Development. 2006;.

[20] Evans P. Streamlining formal portfolio management. Scrip Magazine, 1996; 43: 25-28.

[21] Matheson D., Matheson J. E., Menke M. M. Making excellent R&D decisions. Research-Technology Management, 1994; 37: 21-24.

[22] Ringuest J. L., Graves S. B. Formulating optimal R&D portfolios. Research-Technology Management, 2005; 48: 42-47.

[23] Ringuest J. L., Graves S. B., Case R. H. Formulating R&D portfolios that account for risk. Research-Technology Management, 1999; 42: 40-43.

[24] Matheson J. E., Menke M. M. Using decision quality principles to balance your R&D portfolio. Research-Technology Management, 1994; 37: 38-43.

[25] Skogstad M., Brunoe T. D., Nielsen K., Andersen A. Product Architecture Mining: Identifying Current Architectural Solutions. In Towards Sustainable Customization: Bridging Smart Products and Manufacturing Systems. Springer; 2021; 694-701.

[26] Swink M., Talluri S., Pandejpong T. Faster, better, cheaper: A study of NPD project efficiency and performance tradeoffs. Journal of Operations Management, 2006; 24: 542-562.

[27] Turkulainen V., Ketokivi M. Cross-functional integration and performance: what are the real benefits? International Journal of Operations & Production Management, 2012;.

[28] Vandevelde A., Van Dierdonck R. Managing the design-manufacturing interface. International Journal of Operations & Production Management, 2003;.

[29] Hevner A., March S. T., Park J., Ram S. Design science in information systems research. MIS quarterly, 2004; 28: 75-105.

[30] Hevner A. R. A three cycle view of design science research. Scandinavian journal of information systems, 2007; 19: 4.

[31] Bruch J., Bellgran M. Integrated portfolio planning of products and production systems. Journal of Manufacturing Technology Management, 2014; 25: 155-174.