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Research Paper

Managing product variety under operational constraints: A process-industrial outlook

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Using a newly developed conceptual framework on "platform-based design of non-assembled products," the process-industrial applicability of the framework in production and product design was investigated. In a survey of Nordic process industries the research instrument included a comprehensive questionnaire designed to stimulate respondents to act as "multiple informants". The results indicate that the presented framework challenged company paradigms and working practices, but acknowledged the applicability of many components in the new framework. Moreover, the new findings suggest that the framework additionally can be deployed as an instrument in an assessment of corporate strategic production capabilities. The framework can already serve as a "theoretical coat hanger" for analyzing current company practices, but moreover as a point of departure for company introduction of platform-based production philosophy and a platform-based design of non-assembled products. Apart from the framework used in this study, publications in this area are scarce. The findings fulfill the criteria for a theoretical contribution since the results have both originality and high utility for academics as well as practitioners.

1 Introduction

Many companies in assembly-based manufacturing industries have long invested in the concept of "platform-based product family design" to provide sufficient variety to the market, while maintaining economies of both scale and scope within their innovation and manufacturing capabilities (Jianxin et al., 2007, Robertson and Ulrich, 1998). The concept is generally defined as "a set of sub-systems and interfaces that form a common structure from which a stream of derivate products can be efficiently developed and produced" (Meyer and Lehnerd, 1997). The need for a platform-based product family design in the production of assembled products in manufacturing industries today is indisputable. However, the development of a product platform and its derived family of products is impacted by the heterogeneous nature of the products (Meyer and Lehnerd, 1997).

The cluster of industries generally called the "process industries" spans multiple industrial sectors and generally includes petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, pharmaceuticals, pulp and paper, steel and utilities (Samuelsson et al., 2016). One of the principal differences between companies in the process industries and those in other manufacturing industries is that the products supplied to them, and often delivered from them, are materials or ingredients rather than components or assembled products (Flapper et al., 2002, Frishammar et al., 2012). In a review of the extant literature on platform-based design, only one article (Meyer and Dalal, 2002) related to a process-industrial context was found.

The homogenous nature of products manufactured in the process industries, as well as the intimate coupling between raw materials, production processes and products (Samuelsson et al., 2016), necessitates a well-integrated production and product design philosophy. In a recent study (Lager, 2017), it was concluded that current theoretical frameworks on platform based development of assembled products are not applicable in the process industries. In the latter, a novel conceptual framework for "platform-based production and design of non-assembled products" was developed, introducing a new approach on production and product development in the process industries.

Because of that, it was deemed of interest to inquire in-depth knowledge about present process-industrial awareness or possible use of such an approach, but also to further investigate the industrial applicability of the new construct. To that end, the concepts in the framework was further developed into a questionnaire that was utilized in a survey of the Nordic process industries. The survey results are presented in this study and the content is organized as follows.

In the next section, a frame of reference is given and the previously presented conceptual framework used in this study is introduced. The research strategy and design are then introduced, including the study population and the survey. In the main part of the article, empirical findings from the survey are presented, including comments from the respondents. The research results and limitations are then discussed. Finally, management implications are put forward together with general conclusions from the study.

2 A frame of reference

To facilitate the reading experience, the rather voluminous questionnaire deployed in the survey has been integrated with the presentation of the empirical findings. Because of that, the following frame of reference only introduces the reader to the "core" of the conceptual model and the ideas contained in the framework.

To provide sufficient variety to the market, while maintaining efficiency within their innovation and manufacturing activities, is of interest to companies in assembly-based manufacturing industries as well as in the process industries.

The literature on product variety is largely related to the issue of production and product flexibility (Jack and Raturi, 2003); generally either taking a product design perspective (Belt et al., 2015, Park et al., 2008, Luo et al., 2010), or the development of mathematical models for operational optimization (Daie and Li, 2016, Wilson and Ali, 2014). Postponement, and to maintain products as long as possible is one solution to deal with the increasing variety problem, which was found to be of interest in the food processing industries (Van Campen and Van Donk, 2014). Kahn (1998) provides a general review of the topical area and on using high-variety strategies for a dynamic relationship with customers see e.g. Kahn (1998).

One solution for managing product variety in manufacturing industries is to employ platform-based product design. A basic requirement in platform-based product family design in assembly-based industries is the decoupling of design elements to achieve separation of common elements (platform) from differentiating (non-platform) elements (Halman et al., 2003). In those industries, a modular design with well-designed interfaces is a proven industrial practice to employ, when related process and supply platforms should be developed (Suh, 2001).

Recently, platform-based product family design of assembled products was reconceptualized into a theoretical framework for platform -based design of non-assembled products (Lager, 2017), where platform-based product design was defined as shared logic in product design activities. The conceptual framework relied on early contacts with four informants that further ascertained that "platform-based production design of non-assembled products" was probably a novel construct in several sectors of the process industries. Thus, it was proposed that a platform-based production philosophy and platform-based design of non-assembled products should rely on product platforms, process platforms, and raw-material platforms, which are contained in production platforms. Furthermore, a function-based leveraging strategy was recommended to identify commonalities among product families, production processes, and raw materials as illustrated in Figure 1.

2.1 Research questions for the study

Following the previous discussion, and to close the knowledge gap, the following research questions were delineated for this study:

RQ1 Can "platform-based production and design of non-assembled products" assist in securing product variety while maintaining economies of scale and scope?

RQ2 What is the process industrial relevance and applicability of the conceptual framework and its inherent components for "platform-based design of non-assembled products"?

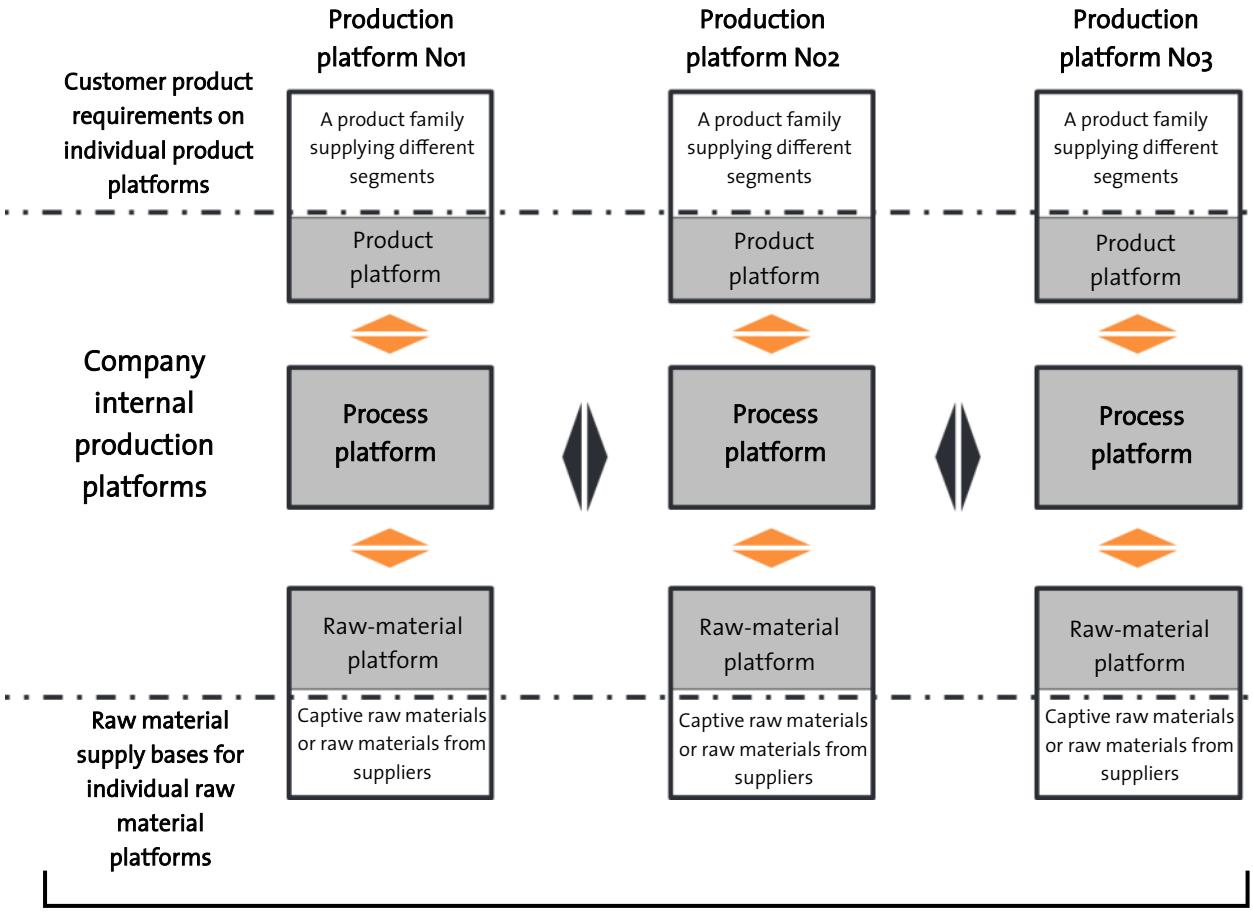
RQ3 Can the framework also be deployed as an instrument for the analysis and assessment of leveraging corporate "strategic production capabilities in a platform-based perspective"?

3 Research strategy and design

The overall research strategy for the theoretical development aimed at establishing the industrial relevance and applicability of the aforementioned conceptual framework, i.e. to inquire about the industrial "state-of-the-art" in the topical area and learn from industrial practices and inquire about the potential industrial applicability of the novel framework. To answer the research questions, a survey of Nordic process industries was selected as the research instrument. The survey was thus primarily an instrument to test and further adapt the conceptual framework to an industrial context, rather than to validate the theoretical models as such.

The use of a survey is an uncommon methodology approach in exploratory research, but in the perspective using the concept and its applicability, it was selected as a proper re-

Figure 1 Multiple production platforms (source Lager, 2017).



search instrument. The respondents were considered as "key informants" (Wagner et al., 2010):

"Key informants report their perceptions of these constructs, rather than personal attitudes or behaviors. In this respect, informants need to be distinguished from respondents who give information about themselves as individuals."

In that respect, the respondents can also be viewed as "multiple informants" since their answers sometimes also related to sectoral conditions outside their own company (Wagner et al., 2010). In the effort of bridging the research-practice divide, the informants were thus asked to contribute with their answers on the numerous open questions in the inquiry, as "judges of the concept-in-use" (Barrett and Oborn, 2018).

3.1 Population of interest and the study population

Although the "population of interest" for the study is the global process industry, it was decided to include only Nordic companies from the process industries; these companies became the selected "study population". The authors' first-hand knowledge of Nordic companies in the process industries aided in the actual conduct of the survey, helped to define the study population and facilitate contact with knowledgeable respondents. The selected companies were located in Sweden, Finland, Norway and Denmark, not necessarily their registered offices, but with major production sites and R&D activities in those countries. Many are major players within their respective industry sectors, have substantial R&D activities and a minimum of 500 employees. The selected industry sectors included the mineral, forest, food and drink, chemical, metal and pharmaceutical industries. The study population was not a random sample, but rather close to being a census for some of the selected sectors of the Nordic process industries (see Table 1).

3.2 Study questionaire

The questionnaire focused on descriptive information gathering, which is an established

Table 1 Survey send-outs and responses from different sectors of the process industries in the Nordic countiers (source: own representation).

	Sweden		Finland		Norway		Denmark		Total		Total %
	Send-outs	Respon-ses	Send-outs	Respon-ses	Send-outs	Respon-ses	Send-outs	Respon-ses	Send-outs	Respon-ses	
Mineral industry	1	1	1	0	1	0	0	0	3	1	33.3%
Forest industry	6	3	4	1	1	0	0	0	11	4	36.4
Food industry	5	1	5	0	0	0	2	0	12	1	8.3%
Chemical industry	5	0	3	1	0	0	1	0	9	1	11.1
Metal industry	9	5	2	1	4	1	1	0	16	7	43.8
Pharma industry	0	0	1	0	0	0	2	0	3	0	0.0
Total	26	10	16	3	6	1	6	0	54	14	25.9
Total %	38.5		25.9		18.8		0.0		25.9		

approach when researching emerging topical areas (Yin, 1994). During the previous development of the conceptual framework, the models and related content were thoroughly reviewed and discussed, therefore a separate "pilot testing" of the final inquiry was not considered necessary. The English language was used in the questionnaires to all respondents, since English is generally well understood and often the "working language" in industrial corporations targeted in this survey. Because "platform-based design" presumably was going to be a rather new subject area for most of the respondents (informants), it was decided to gradually introduce the topical area in the questionnaire, making it a somewhat dynamic reading/answering experience for the respondents. In that respect the rather extensive and informative questionnaire was hoped to emerge as an "interview by correspondence" for the respondent.

3.3 Survey approach

After the companies had been identified, care was taken to find a respondent with intimate knowledge in the areas of product innovation and production. The company "owner" of a platform-based production and design philosophy was targeted as a Technical Director or Development Manager. A named person within each company's organization was usually contacted by telephone before the send-outs, but in a few instances the respondents were only contacted by e-mail. The questionnaires were distributed by electronic mail and the respondents could answer directly through the attached document. The questionnaire was answered by only one respondent in each company. After the send-outs, most of the respondents were reminded either by telephone call or by e-mail after about six weeks. The number of send-outs and responses are presented in Table 1. The final response rate was 25.9 % out of the total send-out of 54 questionnaires. In section 5, response-rates and a possible non-response bias are further discussed.

4 Empirical findings

In the following, each topical area in the inquiry is initially presented with the introductory statement in the questionnaire (S), and afterwards the specific question put forward (Q). The empirical results are afterwards presented as descriptive statistics, supplemented by related comments from all respondents (R). All headings in this section are identical with the questionnaire.

4.1 Securing product variety while maintaining economies of scale and scope within the firm's capabilities

4.1.1 An introduction to the problem area

(S): The need and general importance of platform-based product family design in the production of assembled products in other manufacturing industries is today unquestionable.

To compete in the marketplace, manufacturers have been seeking for expansion of their product lines and differentiation of their product offerings with the intuitively-appealing belief that large product variety may stimulate sales and generate additional revenue. Initially, variety does improve sales as the offerings become more attractive; but as variety keeps increasing, the law of diminishing returns suggests that the benefits do not keep pace. Facing such a dilemma, a company must optimize its external variety with the respect to the internal complexity resulting from product differentiation. Many companies are thus investing in product family development practices in order to provide sufficient variety to the market while maintaining the economies of scale and scope within their manufacturing capabilities.

(Q): Is the above statement relevant and an important issue also for your company (1 = Not at all; 5 = Very much so)?

(R): The respondents' answers to the question had the following statistics: mean = 4.07, std. deviation = 0.73, skewness = - 0.11.
Comments from (industry) respondents after answering this question:

- Expansion of product lines means increased complexity also for marketing and sales (forest).
- E.g., we try to use the same mixture in the "baseboard" and then vary the coating options on top of the paperboard (forest).

- Important to rationalize product lines and to have a "leaner system" (mineral and materials).
- This is very important. We see a constant growth of new "stock keeping units" both for our own brands and especially "private label" brands (food and drink).
- We use the name "attribute brands" that will consist of a number of grades but the aim is to reduce these into a smaller number of offerings (steel).

4.1.2 Company awareness of the concept

(S): In industries producing assembled products, a product platform can be defined as a set of "subsystems" and "interfaces" that form a common structure from which a stream of related products can be developed and produced efficiently, and is thus the common basis of all individual products within a product family.

(Q): Have you previously discussed the concept of "platform-based product family design" in your company as a means to economies of scale for your production capabilities of non-assembled products (1 = Never; 5 = Very often)?

(R): The respondents' answers to the question had the following statistics: mean = 2.77, std. deviation = 1.17, skewness = 0.53. Comments from (industry) respondents after answering this question:

- We have not used the word platform (mineral).
- We do it in practice but it is not an expressed strategy or concept (forest).
- The concept is something that has been used but the terminology has been different (forest).
- I think the oil refinery industry must work this way (petrochemical).
- Yes, indirectly but not in the terms of a defined concept (steel).
- We developed this concept (without the name!!) for a long time. It is a way to optimize the mix in a product family between "commodities" and "specialties" (mineral and materials).
- We indirect think and act this way. Focus on upstream production and late differentiation (food and drink).
- I would say that this is what we aim for with our "attribute brands" (steel).

4.2 Introducing a "production platform philosophy" for the process industries

4.2.1 Proposed definition of a "production platform philosophy" for non-assembled products

(S): The following introduces a proposed new "production platform philosophy for the process industries" and further to its embedded concept "platform-based design of non-assembled products".

A platform-based production and design philosophy for non-assembled products in the process industries, involves the identification and exploitation of the shared logics and commonalities of a firm's products, production technologies and raw materials, in order to achieve leveraged product variety and other customer offerings, while maintaining economies of scale and scope of its production capabilities.

(Q): How industrially relevant is the above definition of a "production platform philosophy" for the process industries (1 = Not useful at all; 5 = Very useful).

(R): The respondents' answers to the question had the following statistics: mean = 4.31, std. deviation = 0.75, skewness = - 0.61. Comments from (industry) respondents after answering this question:

- Can be applied in our case for product A and product B, when processing different raw materials (mineral).
- The concept is definitely very relevant and these principles have been considered for a long time (forest).
- Offering new product solutions by combining fossil and renewable fuels, which both are produced separately in large scale is an example (petrochemical).
- This is very important (metal).
- Even if we use the same process to different products we may need to use very different process parameters and apply different knowledge and expertise to different products. Therefore, even if the definition suggested, all the economies of scale may not be maintained (steel).

- We need to sell our products based on added value for the customer. Therefore we need to identify what properties we can differentiate our product with compared to competitors. Making each or a combination into a platform is a way of explaining this (steel).

4.2.2 Modelling the structural components of a single production platform

(S): The structural components of a production platform is thus proposed to include a well -integrated product platform, process platform and raw material platform producing a family of derivate products, supplying different market segments and relying on a selected captive or/and supplied raw material base (reference to a figure identical to Figure 1 in the present paper).

- The development of a product platform relies on the identification of commonalities and shared logics of customers' present and future product requirements and their translations into well-defined and measurable product design requirements and functionalities.
- The development of a process platform relies on the identification of commonalities and shared process logics of present and future production technologies and unit process architectures for the production of the related product platform.
- The development of a raw material platform relies on the identification of commonalities and shared raw materials and supply chain logics of present and future raw materials and specifications for the related process platform.

(Q): How useful is the above conceptual model of a "production platform" and its embedded platform components for non-assembled products for an application in your company (1 = Not useful at all; 5 = Very useful)?

(R): The respondents' answers to the question had the following statistics: mean = 4.07, std. deviation = 0.73, skewness = - 0.11. Comments from (industry) respondents after answering this question:

- I think it will visualize in a better way the need for processes that are adapted to both raw materials and type of product (mineral).
- The concept is at least partly applied though not defined in line with above (forest).
- To become relevant in the real-world portfolio development there is a need to have proper tools for defining each platform clearly (forest).
- It is quite generic but describes the platform well (petrochemical).
- This is more or less how we work (steel).
- I think we utilize similar thinking already now. I am not sure if such a model would create added value (steel).

4.2.3 Modelling multiple production platforms

(S): A number of production platforms can be identified on an individual production site but could also be stand-alone platforms in a geographically global perspective (Figure 1).

(Q): Could your company's present production situation be translated into the presented model structure in Figure 1 (1 = Not at all; 5 = Very much so)?

(R): The respondents' answers had the following statistics: mean = 4.00, std. deviation = 0.96, skewness = - 0.61. Comments from (industry) respondents after answering this question:

- The main added value in your definition is to demonstrate the links between the three platforms since too often there is an optimization only by one platform (mineral and material).
- Process platforms in my kind of industry could to some extent be linked between production units but not to the full extent (forest).
- Each site may have a different platform but we can also have different platforms (processes) within a site (steel).
- Yes, more generally with some customers you need to have this (mineral and material).
- The figure describes the situation well. In our terminology, the production plat-

forms are production lines at a particular site (petrochemical).
- Yes, but some of our geographically diversified mills only have a very limited platform structure in itself (forest).

4.3 Platform-based design of non-assembled products in the process industries

4.3.1 A proposed product "function-based" leveraging strategy for the development of product platforms

(S): Because products manufactured in the process industries often have a number of well-defined functional properties (attributes), the following definition of a product "function-based" leveraging strategy for platform-based design of non-assembled products is therefore proposed:

After all individual customer requirements for a product family are identified, and their importance ratings within all selected different market segments are assessed, these importance ratings must afterwards be recalculated into importance ratings of all product design requirements for each individual market segment. A "function-based" product leveraging strategy for platform-based design of non-assembled products is then setting target figures for the conceptual development of each product variety, based on the variability of each individual design requirement and commonalities of functional properties within the product family.

(Q): How industrially useful is the definition of a product "function-based" leveraging strategy presented below for non-assembled products (1 = Not useful at all; 5 = Very useful)?

(R): The respondents' answers to the question had the following statistics: mean = 3.50, std. deviation = 1.16, skewness = 0.17. Comments from (industry) respondents after answering this question:

- Although the content as such seems OK, this sounds too complex for being used for communicating the concept (petrochemical).
- We are working in this direction (steel).
- Yes, extremely useful and time to time not so easy to implement. Nevertheless, it is clearly a very good proposal (mineral and material).
- Seems to be a quite theoretical approach not so easy to understand (steel).
- Some functional properties exist, which you could in theory use for developing new future product strategies (forest).

4.3.2 A proposed leveraging strategy for the development of process platforms

(S): (Selected part of introductory statement) In the identification of process platforms, the process technology configuration is a suitable starting point and that the leveraging strategy for process platform identification could be the use of similar unit processes in the total production system. A process platform in the process industries can thus be the foundation for derivate production structures and set-ups that can be termed "process architectures". Such a family of production processes is then based on production technology commonalities and shared process-logics.

(Q): From your general industrial process knowledge and the experiences from your own industrial sector, is the leveraging strategy for process platforms relevant (1 = Not useful at all; 5 = Very useful)?

(R): The respondents' answers had the following statistics: mean = 3.79, std. deviation = 0.98, skewness = -0.09. Comments from (industry) respondents after answering this question:

- This is very dependent on how easy one can switch between different platforms (mineral).
- Standardizing of processes is a key success factor to develop operational excellence. When a transfer is necessary between one platform to another, you save time (material and mineral).
- We have today separate platforms for producing fossil and renewable products (petrochemical).
- Yes, it is somewhat relevant in that we could use this way of thinking when setting up a new product line (steel).
- Pretty natural (food and drink).

- Should the same product be sorted into several families or does it make sense to create a new family comprising the properties of many of the other? (steel).

4.3.3 Alternative scenarios for process platform development

(S): Depending on necessary process technology for existing, improved or completely new production platforms, the following technology scenarios are identified. Which of these scenarios is most relevant for your company's present situation?

1) The company process platform can rely on existing production technology at the production site. (This scenario was applicable for 3 respondents.

2) The company process platform will need complementary purchased production technology. (This scenario was applicable for 4 respondents.)

3) The company process platform needs in-house development of new production technology. (This scenario was applicable for 3 respondents.)

(Q): From your general industrial process knowledge and the experiences from your own industrial sector, are the above scenarios relevant (1 = Not at all; 5 = Very much so)?

(R): The respondents' answers had the following statistics: mean = 4.36, std. deviation = 0.93, skewness = -1.53. Comments from (industry) respondents after answering this question:

- For all our products we can use existing technology but we need in-house development for the adaption to different and new raw materials (mineral).
- Process platform development strategy is not explicitly expressed (forest).
- In-house development of new production technology is nowadays very uncommon (high cost and risk) (forest).
- The tendency in the industry is to opt for reduced product portfolio and a higher applicability of each product to a wider spectrum of application areas. Under these circumstances the tendency is to build production platforms that can embed multiple capabilities into one product rather than variation of products themselves. This has a higher impact on the modularity of a process platform (forest).
- Existing technology shall be leveraged without sacrificing the need for further development, either in-house or with partners. (petrochemical).
- We have the whole spectra: 1) For bulk standard products 3) for "special products," Scenarios 1-2 are most common. Own engineering for "special products" to a smaller degree (food and drink).
- I would say that all scenarios are relevant. For the more mature products we may use existing production structure (scenario 1). For products in the development phase, scenario 2. For products in on-going research, it can be scenario 3 (steel).

4.3.4 A proposed leveraging strategy for the development of raw material platforms

(S): (Selected part of introductory statement) Platform-based design of non-assembled products may differ and which of the below scenarios is most relevant for your company present situation?

1) Company production solely relies on a captive (company-owned) raw material base. In this scenario, the quality of available raw materials will ultimately determine the products and product families that could be produced and supplied to different market segments. This requires an iterative matching of customer needs, process capabilities and available raw material qualities in the development of different Production platforms. (This scenario was applicable for 3 respondents.)

2) Company production solely relies on purchased raw materials on the open market. In this scenario, the product platforms that are responsive to customer and market needs must naturally be the point of departure for the development of existing or new production platforms. (This scenario was applicable for 2 respondents.)

3) Company production partly relies on a captive raw material base and purchased raw materials. In this scenario, the available captive raw material base must be considered together

with optional purchased raw materials on the open market and matched with available or new production technology and market needs in the development of production platforms. (This scenario was applicable for 6 respondents.

(Q): From your general industrial process knowledge and the experiences from your own industrial sector, are the above scenarios relevant for a leveraging strategy for the development of raw material platforms? (1 = Not at all, 5 = Very much so)?

(R): The respondents' answers had the following statistics: mean = 3.86, std. deviation = 1.10, skewness = -0.49. Comments from (industry) respondents after answering this question:

- For some purchased raw materials, the number of suppliers is very limited (forest).
- This is the "bread and butter" skill of product development practice. How to maintain tolerable product efficiency with the variations of raw materials is a key to profitable operations (forest).
- Complex situation, since the "captive" raw materials also can be purchased (forest).
- We may compensate for some variations in the purchased material but only up to a point (steel).
- The supplier is often specified by our customer, and it is difficult to change supplier (steel).

4.4 A final assessment of the proposed concepts and models

(Q): In a final appraisal of "platform-based design" of non-assembled products, could the presented philosophy and models be of interest for your company (1 = Not really; 5 = Most likely)?

(R): The respondents' answers to the question had the following statistics: mean = 4.07, std. deviation = 0.73, skewness = -0.11. Comments from (industry) respondents after answering this question:

- I think the concept will help in visualizing how new product development is related to both processing of raw material and the process development different raw materials needs (mineral).
- The bigger the company is with many production sites, producing similar or almost similar products, with fairly similar technologies, this would be of a very high interest (forest).
- The underlying need for platform-based design is of course very relevant (forest).
- Some of it is already in use; some areas could be further developed in a more systematic way (petrochemical).
- Due to the complex nature of our raw materials, processes and products, it is likely that the proposed concepts might be oversimplified and thus not useful (steel).
- Time to time, it looks too "simple" but in fact it is a very good way to re-question our methodologies and strategies (mineral and material).
- We could certainly benefit from thinking along these lines (food and drink).
- The concept as such could be useful, but it must be simplified as how it is presented (forest).

5 Discussion

5.1 A discussion of empirical findings

The inquiry touched upon an important strategic area for many companies; the respondents' comments were insightful and provided rich, positive feedback, thus stimulating the further development of the conceptual framework. Kumar et al. (1993) elaborate the key informant concept as:

"*Researchers do not select informants to be representative of the members of a studied organization in any statistical sense. Rather, they are chosen because they are supposedly knowledgeable about the issue being researched and able and willing to communicate about them.*"

The information obtained from the respondents proved to be most valuable for the forthcoming development and industrialization of the framework.

5.1.1 On securing product variety and company use of a "platform concept"

The initial findings presented in 4.1.1 indicate that securing product variety while maintaining economies of scale and scope within company manufacturing is considered to be a most important goal in the process industries (mean value 4.1), but one that is somewhat difficult to achieve. The inquiry focused on the relation between the production system and product variety, but one respondent remarked that expansion of product lines also introduces an increased complexity for marketing and sales. Comments from one respondent that supply chain complexity is strongly affected by high product variety underscoring the importance of a company "end-to-end" approach in product innovation, and to consider supply chain complexity (Dittfeld et al., 2018).

In reference to company use of a "platform concept" in 4.1.2, some companies expressed that they "do this in practice" or "we indirect think and act this way", but it is not articulated as an innovation concept or an overall company production strategy. Others responded that "platform-based product family design" is something they aim for, trying to develop operational structures into a more "platform-like mode", even if the term "platform" is never used. However, this behavior and practice is generally not well defined and is not an operational approach that could be described as a "platform-based product philosophy". Referring to Ludwig Wittgenstein's (Wittgenstein, 1921) statement that "Wovon man nicht sprechen kann, darüber muss man schweigen" ("What you cannot talk about, you have to be silent about"), lacking well-defined concepts and articulated development strategies; advanced and enhanced practices are difficult to discuss, communicate and consolidate in organizations.

5.1.2 On the definition of a "production platform philosophy" and the conceptual modelling of production platforms

The integration of raw materials, production technology, and products in the definition of a "platform-based production and design philosophy" in 4.2.1 was considered to be most relevant, and it was rated very high (mean value 4.3). The simplified conceptual model in Figure 1 was considered a key feature in the proposed framework, see 4.2.2. One respondent expressed that: "it will visualize in a better way the need for processes that are adapted to both raw materials and type of product". In 4.2.3, the opportunity to integrate "multiple production platforms", presented in Figure 1, was rated very high. The possibility to link individual platforms in an overall framework was also recognized to "avoid optimization only by one platform". It was commented that each production site could contain several platforms, but possible linkages in-between platforms in a multiple site perspective is interesting.

5.1.3 Managing operational constraints

The results on the process platform leveraging strategy in 4.3.2, and the underlying thought was well received (mean value 3.8), and the proposed "unit process" approach was considered to be relevant or even "natural". Standardization of process platforms was noted as an important issue. In 4.3.3, the three different scenarios for the development of raw material platforms were generally regarded relevant. One respondent expressed this as "This is the bread and butter skill of product development practice. How to maintain tolerable product efficiency with the variations of raw material is the key to profitable operations".

Even after a brief presentation of the concept of integrated knowledge platforms, the respondents probably intuitively recognized that this concept could be of interest in future product innovation (see 4.4.2). One respondent stated that "Integrated knowledge along the whole value chain from raw materials to end products is a key for successful innovation." Finally, in reference to 4.4.3, the overall industrial interest to further explore the conceptual framework in the respondents' own company was rated high (mean value 4.1). Overall the comments were generally supportive and sometimes enthusiastic to the potential applicability of the proposed ideas and the presented framework.

5.2 Research limitations and a discussion of the non-response rate

A consequence of a low response-rate is not only that the sample size is reduced, but that the non-responding companies may represent a select group that could give biased results. There are three major causes of a non-response: no contact, a refusal to answer, or not being able to answer. In this survey the non

-response rate is primarily a result of no contact and a refusal to answer. Six potential respondents declared that they declined to answer, excusing themselves for lack of time for answering surveys of this complexity. The zero response rate for companies in Denmark is somewhat surprising, but considering the topical area for the survey, one can argue that the reason for zero response was not dependent on a different perspective on "platform-based design" compared to companies in the other Nordic countries.

Referring to Table 1, the response rate differed substantially among the Nordic countries. The Swedish figure of 38.5 % and the Finnish figure of 25.9 % are response rates not uncommon in today's difficult "industrial climate for management surveys". The overall response rate could also possibly be related to the new, and for many respondents somewhat difficult, topical area for the inquiry. Some comments from the respondents indicate that the questionnaire was rather difficult to comprehend, while some respondents on the other hand praised the intellectually challenging models and the stimulating content. The response rate from different industrial sectors differ substantially and the highest response rate from the metal industry (43.0%) is acceptable, while the zero response rate from the pharmaceutical industry is not. The differences may not only be related to difficulties to get answers but could possibly be biased by how applicable the conceptual framework is for different sectors of the process industries.

5.3 Major findings and theoretical contribution

One criterion of "good research" is how usable the research results are. This question is further stressed in the presentation of "grounded theory" where the pragmatic criterion of truth is its usability (Glaser and Strauss, 1967). Related to this philosophical standpoint, Whetten (1989) and Corley and Gioia (Corley and Gioia, 2011) cogently defined "theoretical contribution" as the ability to produce thinking that is original in its insight and useful in its application. When it comes to the notion of "originality," a theoretical contribution can be categorized as either advancing understanding incrementally or in a more revelatory or surprising manner (Corley and Gioia, 2011). On the practical utility, Corley and Gioia suggest "prescriptions for structuring and organizing around a phenomenon." The authors of the present study also suggest that the practical utility has two main dimensions: the findings themselves and the form in which the research can be disseminated to practitioners.

In the perspective of both comments from the respondents on the specific questions as well as from the analysis of the empirical data, two rather different but strongly related major findings emerge and constitute the theoretical contributions from this study. First, in the previously presented conceptual framework which was deployed as the research instrument it is initially proposed that it could be used in "platform-based design of non-assembled products" (Lager, 2017). The results from this study indicate not only the industrial need for well delineated frameworks and models, but also that the conceptual model can serve such a purpose. In that respect, the empirical results from the survey advances the scientific position since, in reference to Corley and Gioia (2011), it "improves conceptual rigor or the specificity of an idea and/or enhances its potential to be operationalized and tested." Second, the results from this study additionally indicate that the conceptual framework could be deployed to review and assess corporate strategic production capabilities. In the perspective of these new findings, it is thus proposed that all product families, including all product varieties, should be contained in the following activities:

- Identify and delineate company site specific production platform architectures, and their embedded product-, process- and raw material platforms.
- Investigate and assess the capabilities of each individual platform architecture and its embedded components from the prospect of product variety, flexibility, operational efficiency, process integration and raw material supply conditions.

In consideration of the "utility" aspect, it is argued that the framework is providing industry professionals an instrument for "structuring around a phenomenon"; the area investigated in this study. Moreover, in the overall perspective of "practical utility", the framework has proved to be an excellent communication tool with industry practitioners. A tool not only for

discussions of platform-based product design but also as a guiding framework for an analysis of corporate strategic production capabilities. It is argued that the results from this study thus fulfil the criterion for a theoretical contribution since the results have originality and the utility is high for both academics and practitioners.

6 Managerial implications

In view of the encouraging results from this exploratory study, it is suggested that the conceptual framework already can serve as a "theoretical coat hanger"; a point of departure for introducing and developing a platform-based production philosophy and a platform-based design of non-assembled products in the process industries. Moreover, using the conceptual framework in the development and design of non-assemble products and product varieties could be one avenue to follow in managing product variety under operational constraints.

7 Conclusions

The low response rate from some industry sectors makes it difficult to draw any firm conclusions on present use of "platform-based design of non-assembled products" in the process industries in general, but in answering the first research question, it is indicated that this is a new conceptual idea within this family of industries. The initial finding from the study confirms that all respondents struggle with the problem area and how to improve management of product variety under operational constraints. The results also indicate that the new ideas and models were much in-line with current industrial mental models, but the holistic perspective and new constructs on "platform-based production and product design" also challenged the respondents' present company paradigms and working practices.

Related to the second research question, the overall findings from the survey acknowledged the applicability of many components of the proposed framework, and the need for a well-delineated and more pronounced "platform-based production and product design philosophy" for process-industrial use. The results from this survey will thus be integrated and used in the further development of the framework, making it a clearer, more coherent, and also more digestible for industry professionals.

In reference to the third research question, the industrial relevance and acknowledged applicability of the conceptual framework in this study suggests that it can be deployed both as an instrument for an analysis of companies' present production systems and similar product innovation practices, and for company implementation and deployment of the novel framework. It is finally advocated that both kinds of industrial use could be amalgamated, embedded, denominated and industrially deployed as an overall "platform-based philosophy for production and design of non-assembled products.

To the authors' best knowledge, academic and professional publications in the area of industrial use of platform-based design and production of non-assembled products is scarce. Apart from the conceptual framework deployed in this study, it is argued that the findings from this study thus fulfill the criteria for a theoretical contribution because the results have originality and high utility for both academics and practitioners.

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