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# Conceptual approach to product development process based on supply chain concepts

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## Abstract

There is currently a trend in the Product Development Process (PDP) and Supply Chain (SC) to make this relationship closer and more fluid, presenting a difficulty due to the complexity involved. The complexity of innovation projects can be even more demanding, especially due to the need to launch them in shorter and more assertive terms in the current context of industry 4.0, in which global networks are emphasized in the exchange of information. Given this context, this article aims to conduct a systematic review of the literature exploring the relationship between the PDP and SC. In this way, it was possible to propose a new approach contemplating the conception of the product development process combined with the concepts of the supply chain, such as support for the design and conception of product packaging from an industry in the cosmetics sector. As a result, it was possible to contribute to the existing gap between the integration of these two research areas.

**Keywords:** New Product Development, Supply Chain, Industry 4.0, Supply Chain concepts, PDP, SC.

## 1 Introduction

Currently, the complexity of the operations of the industries and the speed of changes required by consumers, demand that companies have and seek even more agility and assertiveness in what will be offered. In addition to this context, we have industry 4.0, known as the fourth stage of industrialization, production needs to adapt to the constant fluctuations in demand between products, it is necessary to optimize production based on the communication of Internet tools of things and improving the human-machine interface (HMI)[1].

Based on this context, it is necessary that the Product Development Process (PDP) and Supply Chain (SC), narrow and update constantly so that this relationship is more and more synchronized and that innovations occur more efficient. Considering the strategic nature of SC's design feels almost forced to integrate it into the development of products and processes [2] [8] [12] [18] [23] [25]. Although it is widely accepted that product design decisions and their associated supply chain are interrelated, it is unclear

how they interact with each other [3]. The integration and relationship of these large areas, therefore, presents difficulties in sharing / exchanging information and losses in the process. Although this problem has been improved by applying the concepts of industry 4.0 in the use of technology to have full access to all necessary information, the gains and the importance of this alignment between PDP and SC are still unclear. It is from this context that the present work aims to search in the literature the methods and approaches that cover the integration between SC and PDP.

This relationship adds a wide range of processes, whether internal or external, to be coordinated correctly and effectively. Thus, companies need to view the innovation process as a collaborative process, in which a supply chain plays an essential role for success. In this way, a supply chain integration with the management structure, in which each entity can have visibility of other parts of the supply chain, allows the potential for a better production decision (support for product innovation or focus on quality) and, therefore cost savings and reduced response time.

## 2 Systematic Literature Review

The Systematic Review explored works related to the integration of the new product development process and the Supply Chain through the CAPES / MEC Research Portal Platform (Coordination for the Improvement of Higher Education Personnel). This database was chosen because it is one of the most complete available to search for publications, and for that, keywords and their correlates were used that serve the large areas (PDP and SC) crossed together, reaching a total of 23,522 articles. As a refinement, the cleaning and selection of this total were carried out, considering only the articles published in the first quartile (Q1) according to the *Scimago Journal Ranking - 2020* resulting in 138 articles. From this, a more complete analysis of each work was carried out, also using inclusion and exclusion criteria, resulting in 17 most relevant research/articles found in the literature with their contributions and limitations as described in Table 1. Subsequently, these articles were selected based on titles and abstracts, going to 480 works, which were again carried out based on inclusion criteria (Address both subjects as main, be written in English, peer-reviewed, with SJR close to or greater than 1 and JCR greater than 1) and to remove duplicate articles. As a result of this process, 138 works were analyzed more deeply, resulting in 17 most relevant articles, which were read in full, allowing to bring their contributions and as described in Table 1.

**Table 1.** The most relevant research works founded in the literature review.

| Author/Year           | Contributions  | Limitations  |
|-----------------------|--|--|
| Nihtilä, Jukka [4]    | Provides information about the complex process of cross-functional integration at the beginning of NPDP  | It neglected the integration between R&D and other commercial functions other than production. Lack of knowledge about the end customer, supply and marketing. |
| Appelqvist et al. [5] | The Article deals a lot with the term reengineering and focuses on the supply chain without changing the PDP. It identifies the lack of companies to recognize their business situation and act accordingly. | Focuses a lot on the systems modelling and development of a Platform, in addition to the lack of application cases to evaluate the effects.                    |

| Author/Year              | Contributions   | Limitations   |
|--------------------------|---|---|
| Blackhurst et al. [6]    | It features modelling of mathematical functions performed within the SC, which allows the user to model decisions and using the results to assist in SC reengineering decisions and product and process design decisions  | Tested on sampling, without being applied to a wide variety of PP and SC, which can be a problem the applicability of the large-scale approach due to a large number of variables and the uncertainty of the operation. |
| Van Hoek and Chapman [7] | The article reinforces the need to consider SC stakeholders and their alignment in advance so that product availability is guaranteed on the launch date  | It only presents areas for future research and does not go into any depth.  |
| Ellram et al. [21]       | It identifies that there are no works that deal with the 3 dimensions (Supply chain, product and process) - 3DCE. It proposes some ways of working together to meet the needs of the client.                              | Lack of modelling that allows total understanding and intrinsic needs.  |
| Seuring [9]              | It brings a framework of the product-matrix relationship with an alternative approach, which analyzes the content of the decision together with the perspective of the process captured in the five Ps of the SC strategy | Only one of the five applied cases cover all phases of the product's life cycle and brings a more focus on the post-market.   |
| Pero et al. [10]         | It brings stronger evidence that the performance of SC depends heavily on the alignment of the NPD-SCM. Affirms that modularity does not necessarily reduce the complexity of the configuration                           | It does not address the issue of the need for internal alignment and product characteristics and their alignment impacts.   |
| Droge et al. [11]        | The article integrates SC with a company's product strategy, bringing a positive link between product and process modularity and service performance  | The work limits the sample size, being very small and can lead to the error of accepting or rejecting the sample, in addition to being limited to a single sector   |
| Baud-Lavigne et al. [22] | It brings a more focused study on standardization, which is the correlation between the level of standardization and the gain to SC, with demand being a key parameter.   | It was not able to model the problem considering both the standardization and the allocation of the product, and the solution is highly complex   |
| Madenaset al. [13]       | Provides publications in the information flow area in SC and provides a comprehensive review of representable articles for each phase of the product life cycle   | Focused on systems to integrate fields and not necessarily how to do that   |
| Chiu and Okudan [14]     | The Method helps to better understand the impact of different levels of modularity and determine which product architecture to apply according to market situations, from the initial stages of the project               | The model does not analyze management criteria and the method considers only the assembly project (DFA) and the supply chain project (DFSC)   |
| Morita et al. [15]       | Normative model, in which the company implements initiatives to strengthen the SC process, to ensure a match between the product's characteristics and the SC process, increasing competitiveness.                        | Model is not a derivative of observations of the real behaviour of the company, in addition to using the assumption of stable and unchanged demand.   |
| Pashaei and Olhager [16] | The Article shows the type of design of SC corresponds to the type of design of the product.  | The Article fails to bring a holistic view of the integration of SC and PD  |
| Zimmermann [17]          | It presents a model that synthesizes the main practices identified to improve innovation performance, involving actors internal and external to the organization, such as the SC  | It is a systematic review with a new model that is unclear and without application focusing on innovation.  |
| Khan et al. [24]         | The article states that companies can create competitive capabilities by integrating product design with SC through management  | It does not investigate how opportunities and challenges change over time. In addition to not investigating its similarities and differences in different sectors.  |
| Tolonen et al. [19]      | The NPD process must manage pure product development activities and SC capacity building activities. This requires alignment and cooperation between the NPD and SC processes   | Design par excellence (DFX) was left out of the analysis to keep the focus on the SCC, in addition to being an empirical analysis of a single company.  |

| Author/Year                  | Contributions   | Limitations  |
|------------------------------|---|--|
| Primus, and Stavroulaki [20] | It brings about Interdependence between PD and CS, focusing on the compatibility between PD variables and their SC, how they affect the effectiveness of NPIs and the quantitative benefits of alignment decisions. | The Article made the alignment between several products of the same line, and generations of the same product, going beyond the launch, besides not addressing the potential causes of misalignment and the transversal approach |

### 3 Content Analysis

From the Systematic Review, it was possible to better understand the gap concerning the integration of the supply chain since the initial phases of the PDP, requiring the development of an approach that would treat the process holistically from pre-development to production and product availability. This is a preliminary conceptual approach to product development based on supply chain concepts, called Supply product development (SPD) as illustrated in Fig 1.

This context presents in the two large boxes, in which the first presents the PDP process composed of its macrophases (Pre-Development, Development and Post-Development), steps and phases, and the second box presents the supply chain area and what is included. Both have an arrow that feeds back into the process, as the lessons learned from projects and supply carried out, whether successful or unsuccessful, must be available in the data to prevent them from recurring.

The PDP Box brings a greater highlight to the Development macrophases highlighted in yellow in the figure, which is composed of its five phases (training project, conceptual project, detailed project, product preparation and launch). The box that represents the SC, on the other hand, brings the processes inserted within it (suppliers, industry and distribution, retail and customer), and unlike the PDP, the SC does not have well-defined steps and macrophases. In addition, this is based on no operation support.

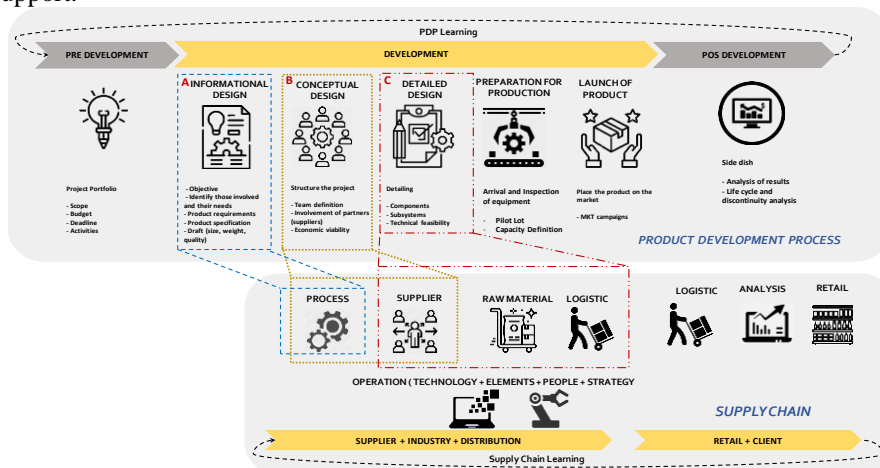


Fig. 1. Research Context.

Regarding the PDP, Pre-Development is applied to all types of Innovation projects and is the moment when the scope of the project is discussed, aiming at the objective to be achieved within a stipulated budget. At this stage, it is important to understand the desires that the consumer expects from the product, ensuring the strategic orientation of development. For this proposed approach, this step is maintained, in comparison with other existing methods, however, it brings the inclusion of supply chain representatives in the discussions, to reduce uncertainty and eliminate eventual mapped problems of the project, such as distribution issues, lead production time and complexity, even if on a macro basis, based on market demand.

Moving on to the Development of macrophase, it consists of 5 phases. The first, the informational project, uses information received from the previous step and translates these into technical characteristics according to the target audience. At this stage, the presence of representatives from SC already assists in the prospecting of suppliers, based on the level of service, technical knowledge, commitment and existing warehouses. The second phase (conceptual design) is the time for more detailed definitions, related to the creation, representation and selection of solutions for product design, in addition to the definition of the team and supplier involvement. In this, the representatives of SC, evaluate and assist in the creation of the sketches, in addition to the inclusion of suppliers, already duly evaluated, with the product options available in the portfolio of each or in the manufacturing of new moulds in order to meet the requirements listed. The third stage, known as detailed design, generated the product specifications, as a definition of the raw material and material of the product and its components, including the accepted tolerances, presenting a control plane and a prototype.

Details related to packaging, storage and transport are also pre-defined, which makes the presence of SC necessary, as well as an analysis of operations (planning, suppliers, engineering and logistics), to generate market, aesthetic and economic evaluations. In the preparation of the product, known as the fourth phase, the Pilot Lot is carried out, which generates the integration of the product with the production process (production and maintenance) and SC is already more present in other existing models. The fifth phase is the product launch that involves the implementation of the launching plan (marketing) and the operations plan (production), with the initial production monitored, and it is the moment that planning efforts are proven in scheming the production and the arrival of all inputs, packaging and equipment, guaranteeing production and supply.

As shown in figure 2, the first 3 phases are evident, with the dots showing where the PDP interfaces with the supply chain related to them are. Highlight A, in figure 2, brings the interface of the informational design, with the process part and the highlight B, of the conceptual design, interconnected to the process and to the supplier in a more evident and decisive way. Highlight C, on the other hand, features the detailed project, making it more integrated with the suppliers, raw materials and logistics, since it is the moment when specification decisions are made, the process at the supplier is analyzed and also the logistics part of manufacturing and availability to the customer.

The last post-development macrophase, which is also not the focus of this approach, but is important because it considers production at scale itself, and makes the assessment of the acceptance of the target audience before the launch and the total life cycle of the product. With well-planned planning, good results should be made available for

this macrophase just to be managed. Fig. 2 illustrates the proposal for a new approach to the Product Development Process based on the Supply Chain perspective focusing on the product packaging. This approach brings the insertion of the Supply Chain in the product development process.

| MACROPHASE                  |                           | PRÉ DEVELOPMENT                   |                                |  | DEVELOPMENT                                    |  |                                      |  | PÓS DEVELOPMENT   |                                |                                      |                                |
|-----------------------------|---------------------------|-----------------------------------|--------------------------------|--|--|--|--------------------------------------|--|-------------------|--------------------------------|--------------------------------------|--------------------------------|
|                             |                           | Initiation                        | Planning                       |  | Projecting                                     |  |                                      | Implementation                               | Production        | Maintenance                    |                                      |                                |
| PHASES                      |                           | 1                                 | 2                              | 3  | 4  | 5  | 6                                    | 7  | 8                 | 9                              | 10                                   | 11                             |
| STAGES                      |                           | Demand statement                  | Scope definition               | Project planning                               | Project Informational                          | Project Conceptual                       | Project Detailed                     | Preparation of Product                       | Launch of Product | Mass production                | Analysis of results after the launch | Monitor the product life cycle |
|                             |                           | Project evaluation and guidelines | Acceptance test and discussion | Evaluation of project criteria and feasibility | Identify stakeholders and product requirements | Definition of product, team and partners | Components and technical feasibility | Pilot batch testing and equipment inspection | Market insertion  | Monitoring of mass productions | Performance testing                  | Market acceptance test         |
| Process of the Supply Chain | Decision and Applications |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
|                             | Supplier                  |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
|                             | Raw Material              |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
|                             | Logistic                  |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
|                             | Analytical                |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
|                             | Retail                    |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
| TOOLS                       |                           |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
| QFD                         |                           |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
| DFX                         |                           |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
| RB                          |                           |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |
| OTHERS                      |                           |                                   |                                |  |  |  |                                      |  |                   |                                |                                      |                                |

Fig. 2. Proposed Approach (SPD).

## Final Discussion

This study presented in this paper has mapped in the literature the integration of PDP and SC. Based on a systematic review, 138 relevant articles were identified after refinement, 17 of them were classified as the most important for the research exploration. It was possible to identify existing contributions and limitations in the relevant research works, which highlighted the gap in the literature of the lack of an approach that treats the Supply Chain (SC) together in the Product Development Process (PDP) in a holistic way. For the proposed approach, the whole context behind the subject was exposed, showing how the PDP could be arranged within organizations, with more predefined macrophases and steps, and how the SC can be classified and correlated with it, given its complexity.

The approach proposes the insertion of representatives of SC in the last stage of pre-development, even if it is more superficially, and being of extreme need from the beginning of the Development until the end of the PDP. This interaction helps to reduce time, costs and gains in quality and agility.

Changing the PDP considering the SC can be quantified by the time of the product development cycle, which tends to decrease, reducing design errors, avoiding rework, increasing the final quality of the product (different teams working from the same point of view) and assertiveness in decision points.

The approach, already being applied in the PDP process of a company with a focus on packaging (jar of body moisturizer), so that the authors could evaluate its effectiveness and efficiency. There is also a cultural change in the PDP process development teams, considering the limitations of the supply chain, going beyond the needs of the product considering the production restrictions.



In summary, this study sought to identify what was the most suitable way for integrating the PDP with the SC, entering a gap on how this occurred holistically, and based on this observation, proposing a new approach for the integration of the two great areas, as well as to propose future studies with the application of this to stimulate and verify the same process in the more complex products development. It is believed that the application can be extended to other industries such as automotive and pharmaceuticals, however, we may have other specific limitations in each field.

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