Foundation of the integration of supply chain decisions in new product development: A systematic literature review and conceptual framework

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Abstract

The purpose of this study is to identify and classify supply chain decisions, which have critical roles in new product development. Supply chain management completes the missing part of the new product development puzzle and provides a holistic view on various operational aspects such as on-time product launch, capacity utilization, inventory management, and accurate order processing. Findings of this study are presented in a conceptual framework. Identified supply chain decisions are classified in a generic new product development model based on the main logistics drivers such as supply, manufacturing planning and control and transportation, to increase the understanding about role of different logistics drivers in different phases of new product development.

Keywords: Supply chain management, new product development, decision-making

Introduction

Constant alteration in the markets, which is characterized by shortened product life cycle, increased product variety, volatile demand patterns, and high technology clockspeed, push companies to change their ways of thinking (Fine, 1998; Fixson, 2005). However, companies still need to compete based on delivering the right product at the right time, in the right place with the affordable prices. Supply chain management (SCM) does not concern with only managing the materials flow outside of the company borders but also concerned with collaboration of business units within the company to achieve the goals of, for instance, new product development (NPD). Companies need to keep their product portfolio updated and the supply chains need to be capable of controlling increasing number of new product introductions to be able to fulfil customers' requests and stay competitive (Abdelkafi et al., 2011). The extent of SCM

integration affects success or failure of NPD substantially. SCM operations ensure that critical aspects are taken care of during NPD such as readiness of materials for production, readiness of finished products for launch and on-time placement of the products in the market (van Hoek and Chapman, 2006: van Hoek and Chapman, 2007: Hilletofth and Eriksson, 2011). Existing studies approach NPD-SCM integration by explaining the relationship between some certain variables such as early supplier involvement in NPD or matching product architecture and supply chain configuration. Limited amount of study takes decision perspective, which enables the researchers to integrate more perspectives and map interdependencies among the decisions (Krishnan and Ulrich, 2001; Chiu and Okudan, 2011). Therefore, purpose of this study is to identify and classify supply chain decisions, which do have critical role in NPD in terms of increasing efficiency, profitability, and exploiting new resources and ideas for product development. In order to fulfil purpose, the following research questions should be answered: (1) *What supply chain decisions are critical to consider in new product development?* and (2) W*hen identified supply chain decisions should be considered?*

This paper is organized as follows: a short presentation of NPD and SCM concepts will be given in Section 2, where theoretical framework is prsented. Research design is presented in Section 3. After that, findings and the conceptual framework are presented in the 4th section. Finally, the study will end up with a discussion and possible scenarios for future research.

Theoretical Framework

Supply Chain Management

From focal companies point of view, logistics systems have had more simple structure in the past, which was characterized by lower production volumes in fewer facilities with very basic level of integration towards suppliers and customers. Today's supply chain systems turn out to be more complex systems, which needs to deal with increasing number of facilities on a global scale with more intense integration between customers and suppliers (Jonsson, 2008; Chopra and Meindl, 2012). Complexity increases as focal companies develop relationship with the second and even third tiers suppliers and customers. Focal companies need to ensure that they provide solid flow of product and information within the plant and coordinate themselves with the other supply chain partners as well (Harrison and van Hoek, 2008). In the context of this study, SCM refers to planning, design and management of efficient material, information and monetary flows within the focal company and across the supply chain partners in order to deliver value-added products to the market (Jonnsson, 2008; Chopra and Meindl, 2012). A supply chain system consists of various logistics drivers that provide coordination and communication inside the focal company and among its partners. Table 1 summarized logistics drivers and definitions of their tasks, which will be used in this study. It is important to understand the role of each function to be able to understand decision-making mechanisms of each function. This is necessary because efficient execution of logistics function is needed to accomplish operational and strategic targets.

Table 1: Logistics drivers of a supply chain

Logistics drivers	Task	Reference
Supply	Supply operations focus on the identification of required materials, selection of the suppliers, creation of purchasing orders and tracking the materials, which will be received.	(Jonsson, 2008)
Manufacturing planning & Control	Address the decisions on the acquisition, utilization and allocation of production resources to satisfy customer requirements.	(Graves, 1999)
Packaging	Address the decisions on the appropriate packaging for attracting customers' attention, making storage and transportation of materials easier and safer, and considering environmental issues.	(Johansson and Johansson 2006; Hellström and Nilsson, 2011)
Transportation	Decides how materials and finished goods will be moved from source point to the target point. Transportation concerns with the decisions regarding selection of transportation mode, route planning, and load planning.	(Johansson and Johansson 2006; Jonsson, 2008; Sunil and Chopra, 2012)
Material handling	Material handling focuses on the movement of the goods inside of the plant and material handling operations concentrate on receive and dispatch of the goods, arrival checks and quality control.	(Johansson and Johansson 2006; Jonsson, 2008)
Storage	Physical stock keeping of the goods within production facilities or warehouses. Storage also concerns with layout design of storage spaces	(Johansson and Johansson 2006; Jonsson, 2008)
After-market and Reverse logistics	Aftermarket and reverse logistics concentrate on spare-part supply, identification of return and receive of the returned items from the customers.	(Jonsson, 2008)

New Product Development

NPD is a set of parallel activities, where different actors transform a market opportunity or an idea into a product surrounded by tangible and intangible attributes (Takeuchi and Nanoka, 1986; Krishnan and Ulrich, 2001; Ulrich and Eppinger, 2012). NPD is illustrated in various ways in the existing literature. In this study, the generic product development process (GPDP) is used as a base of our argument (Ulrich and Eppinger,2012). Main motivation behind of this choice is that GPDP emphasizes the participation of other departments (i.e marketing, sales, general development) that extends the purpose and scope of NPD towards being more innovative and responsive. Previous studies analyse NPD on two different levels: Project level (Leonard-Barton, 1992;Wagner and Hoegl, 2006) and process level (Griffin, 1997; Lin and Piercy, 2012). In the context of this study, NPD process is used as a unit of analysis. GPDP is a clear example of NPD from process level perspective, which is established based on well-defined stages and gates. Stage-gate model was defined first by Cooper (1994) as a conceptual and operational guide to carry out NPD process from embryo stage to product launch. Stages refer to different phases of NPD and gates act as decision-making mechanisms in between the stages.

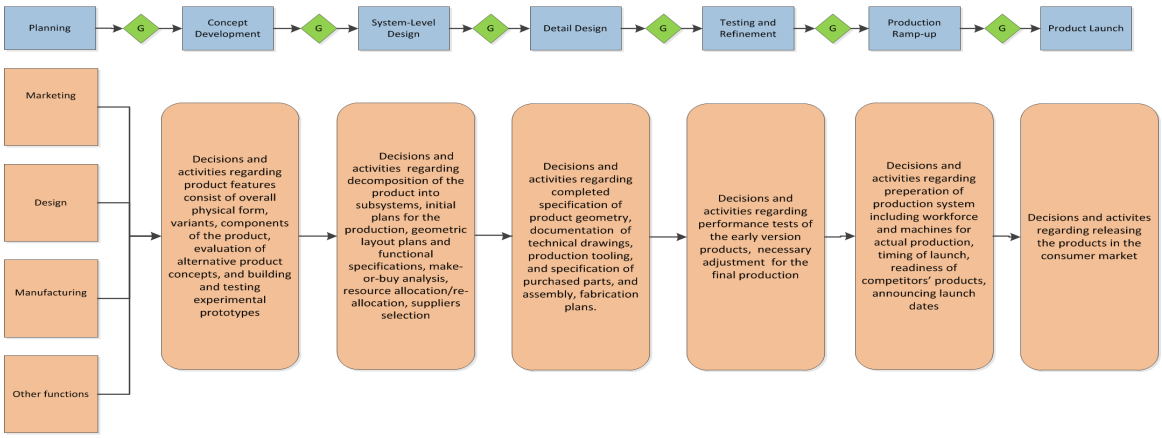


Figure 1: Generic product development process (Adopted from Ulrich and Eppinger, 2012)

GPDP starts with planning of activities in marketing, design, manufacturing, R&D and finance. Then, it continues with concept development, system-level design, detail design, testing & refinement and production ramp-up stages. In addition to original GPDP model, product launch stage was added to the model. Recently, NPD processes need to be more adaptive and flexible due to the volatile and uncertain characteristics of the market and the demand. Cooper (2014) argues that this circumstance forces companies to change their strategies in a way that permits customer involvement in different stages. It is also mentioned that prototypes can be presented to the customers for testing in each stage. Thus, companies can get useful feedbacks from consumers to do necessary revisions.

Research Design

This study is designed as a systematic literature review, which provides transparent and systematic routine for data collection, analysis and presentation of the findings (Jesson et al., 2011). Systematic of the review is based on a review protocol, which helps the authors to ensure quality, reproducibility, consistency and transparency of their study. Review protocol used in this study consists of three major steps: Data collection, data analysis and data synthesis. In the next sections, how each step of the systematic review is handled will be explained.

Data collection

Data collection consists of three steps: (1) Identification of keywords, (2) specification of exclusion and inclusion criteria, and (3) database search. Following keywords were used to generate keyword combinations: Product design, process design, supply chain design, product development, supply chain management, supply chain involvement, supplier involvement, supplier integration, manufacturing, product structure, product architecture, and concurrent engineering. Then, dual and triple keyword combinations were created with the help of a computer program. 69 combinations were chosen out of 444 combinations. Exclusion and inclusion criteria were set based on language, time frame, field of research and type of publication. Scopus is used the database, which are used for sample search. Scopus involves many types of publications, however only articles, which are written in English and published in peer-reviewed journals, were included due to quality assurance and sample covers all times until 2013. All subject areas covered by Scopus were included in order to avoid risk of missing important studies. As a result of search, 1278 papers were identified on Scopus. Final sample consists of 106 papers after abstract and detailed content reviews.

Data analysis

Pattern matching and explanation building are two methods for analysis and synthesis of highly intense qualitative data (Yin, 2009). Data analysis was done via identifying different categories in the reviewed sample and listing identified decisions based on these categories. Categories refers to the concepts, which were used by the authors to explain SCM-NPD integration. Four categories identified: Supplier involvement, supply chain configuration and design (SCCD), concurrent engineering/3DCE and logistics involvement. Papers in each category went through a detailed review in order to find existing critical supply chain decisions. Data collected as a result of the analysis is presented in Table 2.

Data Synthesis

Synthesis was completed in two stages: (1) Re-categorization of supply chain decisions based on logistics drivers and (2) allocation of the decisions in NPD process model. First, all decisions were refined and re-categorised in another table according to their relevance to different logistics drivers. Selection of decisions was made based on the expert knowledge of the authors. In order to avoid bias, each author check validity and consistency of decision specified by other authors. In the second step, each decision is placed in conceptual framework based on the characteristics of each NPD stage and logistics drivers.

Findings and Conceptual Framework

In this section, findings of the entire study are represented. Presentation consists of three steps that start with identification of supply chain decisions that appear in the existing literature. In the second step, identified decisions are refined and they were categorized based on the seven logistics drivers, which were introduced earlier. In the last step, simplified and re-categorized decisions were placed in the conceptual framework, which aims to increase the understanding of what type of critical supply chain decisions should be considered in NPD and when they should be consider among different stages of NPD process. Each step will be explained further in the upcoming sections.

Identification of critical supply chain decisions

In the identification process, focus is only on the supply chain decisions, which are currently considered in NPD process in the existing literature. In this first step, decisions are listed under the following categories supplier involvement, supply chain configuration and design and logistics involvement. Earlier, four categories were presented however concurrent engineering/3DCE was taken out while listing the identified decisions since the decisions addressed in concurrent engineering/3DCE can be easily grouped under the other categories. Table 2 shows the identified decisions and further explanations about the decisions and how they evolved over the time will be discussed in the following parts:

Supplier involvement: Salvador and Vilena (2013) argued that a well-structured collaboration between focal company and its suppliers adds value to the product development and manufacturing and provides substantial improvements in the new product that will be designed. In the literature, decisions regarding supplier involvement focus on types of supplier involvement based on their expertise (Ragatz et al., 2002; Petersen et al., 2005; Van Echtelt et al., 2008), supplier selection criteria, timing of involvement, degree of responsibility given to the suppliers and risk sharing (Birou and Fawcett, 1994; Ragatz et al., 2002; Petersen et al., 2005; Parker et al., 2008).

Supply chain configuration and design: SCCD concerns with the decisions about possible supply chain network design alternatives, assignment of products to the production facilities, and optimization of product flow between different facilities (Nepal et al., 2011). SCCD involves the decisions with regard to potential stocking points for inventory; number and location of production and logistics facilities (Huang et al, 2005; Fixson et al, 2005), selection of places for production, and warehousing facilities based on make-or buy decisions (Zhang et. al, 2008).

Logistics involvement: Decisions in this category focus on decoupling point and postponement strategies, choice of transportation mode based on transportability

requirements and design of materials feeding systems (Dowlatshahi, 1996; Johansson and Johansson, 2006). Lately, some studies also emphasized increasing role of purchasing during early supplier involvement in NPD (Schiele, 2010). Moreover, studies focused on packaging points out important logistics aspects in NPD such as role of packaging and design of appropriate product-packaging combination based on customers' requirements (Klevås, 2005; Hellström and Nilsson, 2011).

Table 2: Identified supply chain decisions

Supplier involvement
Types of supplier involved based on their area of expertise
Supplier selection criteria
Time of supplier involvement
Degree of suppliers' responsibility
Deciding level of supplier support (administrative, technical, or idea support) and power equilibrium between buyer-supplier
Communication/ communication tools
Frequency of communication
Order frequency
Supplier-components combination (who produces, which parts, who assembles)
The level of risk and task sharing
Supplier performance evaluation criteria and methods
Roles of suppliers in different phases of new product development
Design of material feeding systems
Supply chain configuration and design
Supply chain network design alternatives
Design of production facilities based on make-or-buy decisions
Considering cost of:
Processing and facility investment for open facilities
Inventory holding
Safety stocks located a different tiers of supply chain network
Finished items at each stage of the supply chain
Items being processes at each stage of the supply chain
Transportation in between parties along the supply chain
Purchasing of raw materials
Order processing
Agreement between buyer-supplier
Backlog and excess inventory
Number and location of facilities:
Production strategies
Warehousing strategies
Distribution strategies (i.e cross-docking, milk-run)
Potential stock points for the inventory
Allocation of different products to different production facilities
Closed loop supply chain design based on recycling strategies, recovery options
Methods and guidelines collection, inspection/separation and disposal of the products
Recovery options/methods based on the amount of toxic substances detected and energy consumed along the supply chain
Logistics involvement
Decoupling point and postponement strategies
Timing of customer involvement
Forecasting tools
Transportability requirements
Transportation mode(s)
Handling and storage equipment
Production and sales plans
Autonomy of decisions-making (centralized vs. decentralized)
Service level targets based on product, price, place, promotion mix, advertising expenditures and pricing strategies
Key performance indicators to analyse product delivery performance
Logistics information system for optimal demand planning and inventory management
Amount of inventory that will be kept throughout the supply chain
Average replenishment batch size
Systems that will enable supply chain members to collect inventory information from distributors and retailers
Safety stock levels
Inventory turnover goals
Level of product availability rates on the shelves
Design and purchasing of packaging based on logistics capabilities and product features
Product/packaging combinations based on customers' needs and requirement
Deciding barcoding, tracking and tracing systems
Different unit loads of different suppliers and transporters
Lean lunch strategies based on responsive and proactive market orientation
Roles and responsibilities of purchasing
Purchasing of raw materials
Allocation of products to production facilities
Negotiating with transporters

Categorization of identified supply chain decisions

In the second step, re-categorization process of identified supply chain decisions will be explained in details. Re-categorization takes an important step toward establishing the conceptual framework. However, it is also important to specify what motivations

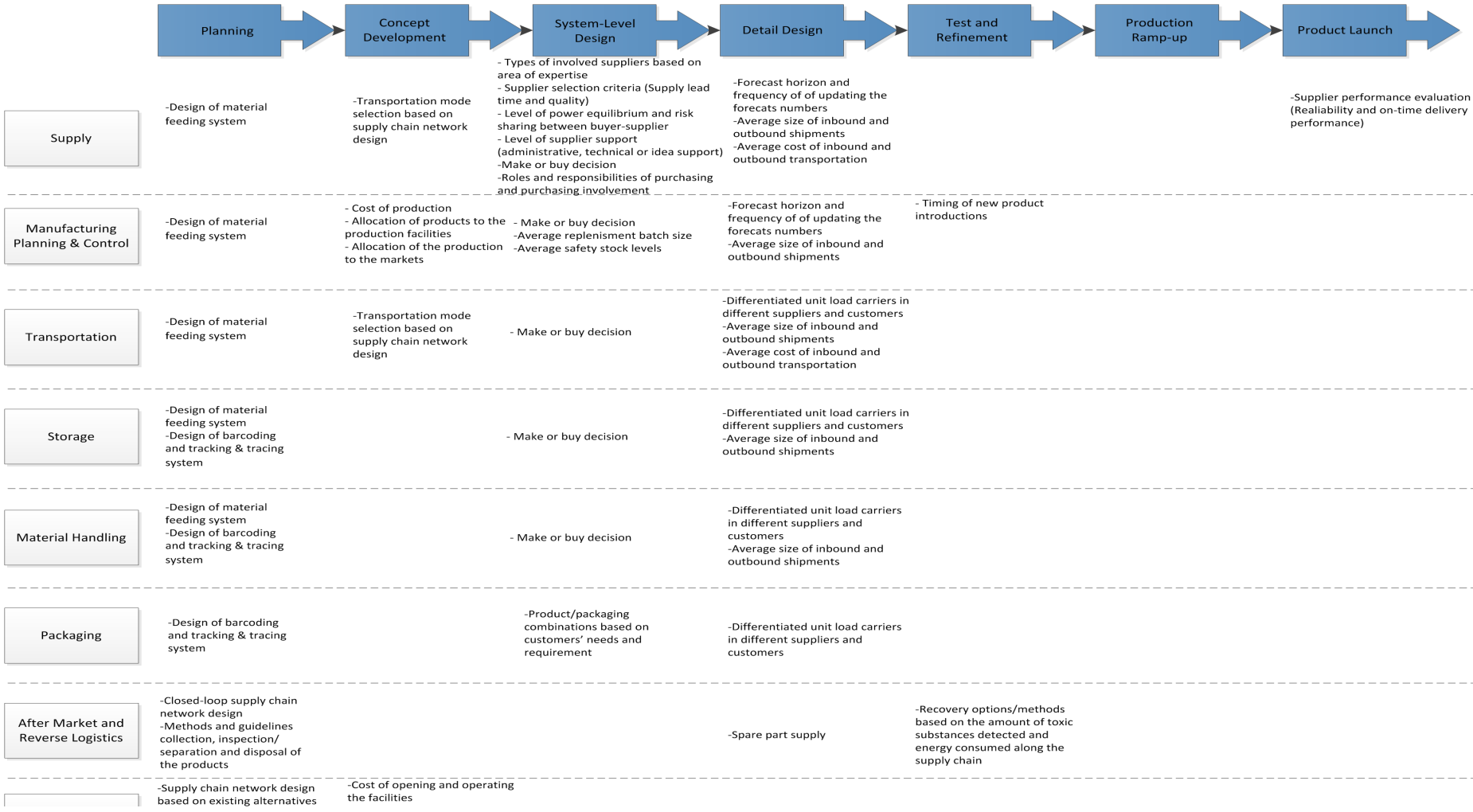
authors do have while categorizing the decisions second time. This step can be seen as a transition step in order to provide more complete picture of conceptual framework and achieve the purpose of this study. Table 2 presents rough decisions, which were derived from the existing knowledge. In the beginning of data analysis process, listing of the supply chain decisions under more broad categories made easier to see the trends in the existing literature and what kind of supply chain decisions were dealt with by the researchers however all these decisions were too complex to integrate into the conceptual model and still provide a refined results. Due to this situation, decisions are grouped considering the tasks of each logistics driver in order to establish more focused and condensed set of decisions. Table 3 presents simplified supply chain decisions, which are critical to consider in NPD, based on specified logistics drivers.

Table 3: Re-categorization of supply chain decisions

Logistics drivers	**Decisions**
Supply	Supplier selection criteria (i.e supply lead time, supply quality) Types of supplier involved depending on area of expertise Supplier performance evaluation (supplier reliability, on-time delivery rates) Level of power equilibrium and risk sharing between buyer-supplier Level of supplier support (administrative, technical, or idea support) Average cost of inbound and outbound transportation Roles and responsibilities of purchasing and purchasing involvement
Manufacturing planning & Control	Allocation of products to production facilities Allocation of production facilities to the market segments Forecast horizon and frequency of updating the forecast numbers Average replenishment batch size Inventory turnover goals Average safety stock level
Packaging	Product/packaging combinations based on customers' needs and requirement Design of barcoding and tracking & tracing system
Transportation	Transportation mode based on network design of the supply chain Average size of inbound and outbound shipments
Material handling	Differentiated unit load carriers in different suppliers and customers
Storage	Differentiated unit load carriers in different suppliers and customers
After-market and Reverse logistics	Closed-loop supply chain design Methods and guidelines collection, inspection/separation and disposal of the products Recovery options/methods based on the amount of toxic substances detected and energy consumed along the supply chain Spare part supply
Overall	Supply chain network design based on existing alternatives Cost of opening operating the facilities Cost of production Cost of inventory carried in each stage of supply chain Cost of backlog or excess inventory Number of production facilities Number of warehouse facilities Postponement and decoupling strategies Autonomy of decision making (centralized vs. decentralized) Design of material feeding system

Conceptual framework: Allocation of critical supply chain decisions

In the last step of the findings, refined supply chain decisions were placed in generic product development process (Ulrich and Eppinger, 2012). NPD is a complex process, which involves many participants from different functions with their conflicting objectives. This framework provides very useful insights about what kind of supply chain decisions should be made in the context of logistics drivers of a supply chain and what common concerns are shared by various logistics drivers. As it us seen in Figure 2, most of the critical supply chain decisions are agglomerated in the early stages of NPD. Existing studies mainly focused on early supplier involvement in NPD (Birou and Fawcett, 1994; La Bahn and Krapfel, 2000; Schiele, 2010).


Planning
Concept Development
System-Level Design
Detail Design
Test and Refinement
Production Ramp-up
Product Launch
Supply
-Design of material feeding system
-Transportation mode selection based on supply chain network design
- Types of involved suppliers based on area of expertise
- Supplier selection criteria (Supply lead time and quality)
- Level of power equilibrium and risk sharing between buyer-supplier
- Level of supplier support (administrative, technical or idea support)
-Make or buy decision
-Roles and responsibilities of purchasing and purchasing involvement
-Forecast horizon and frequency of of updating the forecats numbers
-Average size of inbound and outbound shipments
-Average cost of inbound and outbound transportation
-Supplier performance evaluation (Realiability and on-time delivery performance)
Manufacturing Planning & Control
-Design of material feeding system
- Cost of production
- Allocation of products to the production facilities
- Allocation of the production to the markets
- Make or buy decision
-Average replenisment batch size
-Average safety stock levels
-Forecast horizon and frequency of of updating the forecats numbers
-Average size of inbound and outbound shipments
- Timing of new product introductions
Transportation
-Design of material feeding system
-Transportation mode selection based on supply chain network design
- Make or buy decision
-Differentiated unit load carriers in different suppliers and customers
-Average size of inbound and outbound shipments
-Average cost of inbound and outbound transportation
Storage
-Design of material feeding system
-Design of barcoding and tracking & tracing system
- Make or buy decision
-Differentiated unit load carriers in different suppliers and customers
-Average size of inbound and outbound shipments
Material Handling
-Design of material feeding system
-Design of barcoding and tracking & tracing system
- Make or buy decision
-Differentiated unit load carriers in different suppliers and customers
-Average size of inbound and outbound shipments
Packaging
-Design of barcoding and tracking & tracing system
-Product/packaging combinations based on customers' needs and requirement
-Differentiated unit load carriers in different suppliers and customers
After Market and Reverse Logistics
-Closed-loop supply chain network design
-Methods and guidelines collection, inspection/ separation and disposal of the products
-Spare part supply
-Recovery options/methods based on the amount of toxic substances detected and energy consumed along the supply chain
-Supply chain network design based on existing alternatives
-Cost of opening and operating the facilities

Early stages refers here to system-level design stage, where key suppliers are identified for the key components and supplier selection process starts (Ulrich and Eppinger, 2012). Theoretical framework provides useful details about some particular decisions, which need to involve more than one logistics drivers. For instance, detail design is yet another important stage of NPD process, where product design is confirmed, raw materials are chosen and procurement orders are established for the selected materials and tooling (Ulrich and Eppinger, 2012). In this stage, focal company needs to make some certain decisions, which are related to units load carriers that are used for handling and carrying the materials such as pallets. Standardised unit load carriers play an important role with regard to vehicle utilization, transportation efficiency and space utilization while storing the items in warehouses (Hellström and Nilsson, 2011). However, different infrastructures of global markets in terms of transportation and material handling cause using unstandardized unit load carriers and this circumstances force companies to focus more on their decisions with regard to packaging, storage, transportation, and material handling. Namely, it becomes more important for the focal company to consider packaging issues in the early stage of product design and configure its operations considering different unit load carriers of its suppliers and its customers.

Besides the decisions placed in different stages of NPD and different logistics drivers, some decisions should be made in the planning and conceptual development stages of NPD process ad should be followed up during entire NPD process. These decisions and activities are grouped under the name of "Overall". Decisions and actions taken in this category help focal company to make sure that the system is working and the decision-making process is being done accurately. For instance, cost analysis of some particular supply chain decisions can be done in the concept development stage such as cost of opening and operating facilities, cost of carrying inventory in different phases of NPD or cost of having backlog. It is crucial to make this decisions as early as possible and follow up them continuously to observe whether focal company keeps its financial targets and provide a balance between its expenses and revenues. Eventually, conceptual framework is established without considering any particular type of industry, product, or supply chain. However, it is important to emphasize that the similar decisions can have different impacts on companies' processes based on type of the product, industry, company culture, customer portfolio, and market conditions.

Conclusions And Further Research

The integration of supply chain decisions into NPD provides firms with a new perspective in terms of transforming their value creation process (Holweg and Helo, 2014). It also brings operational flexibility, increased resource utilization, higher service levels, and reduced operational risk. The reported research findings show that critical supply chain decisions are piled up in the very early stages of NPD and that the existing studies have focused on the early stages while quite few studies have focused on the later stages. This implies that the current knowledge is limited with regard to supply chain decisions that are made in the later stages of NPD. The contribution of this research work is twofold: Firstly, the framework shows the critical decisions to consider and the stages to make these decisions in. Intensive decision-making points and critical decisions can be seen clearly in the proposed framework. Secondly, the framework sheds light on possible investigation areas for further research efforts. As a future research suggestion, the framework should be tested in different empirical settings, for instance case studies can be used to compare the findings to the decision-making in a real life setting. In addition, later stages such as testing and refinement, production ramp-

up and product launch can be analysed in order to see what kind of critical supply chain decisions that are made during these stages, for providing more insight about the decision-making process during the later stages of NPD.

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