PERFORMING SUPPLY CHAIN DESIGN ACTIVITIES DURING PRODUCT DEVELOPMENT PROJECTS: A SYSTEMATIC LITERATURE REVIEW

Ewout Reitsma
Department of Supply Chain and Operations Management, Jönköping University, Jönköping 551 11 Sweden, E-mail: ewout_reitsma@hotmail.com

Per Hilletofth
Department of Supply Chain and Operations Management, Jönköping University, Jönköping 551 11 Sweden, E-mail: per.hilletofth@ju.se

Eva Johansson
Department of Supply Chain and Operations Management, Jönköping University, Jönköping 551 11 Sweden, E-mail: eva.johansson@ju.se

ABSTRACT
The purpose of this research is to provide a state-of-the-art overview of the supply chain design (SCD) activities that an OEM can perform when developing new products. This purpose is realized by systematically examining peer-reviewed journal articles written in English. The search strategy adopted in this research is based on selected databases and keywords. Cross-referencing is used to identify additional relevant articles. This resulted in a synthesis sample of 93 relevant articles. From this synthesis sample, a set of SCD activities that can be performed by OEMs during product development projects are extracted. These activities are discussed by using a subset articles (47) from the synthesis sample.

Keywords:
Supply chain design, integrated product development, concurrent engineering, design for x, systematic literature review

1. INTRODUCTION
Product development (PD), understood as the key strategic activity of identifying customer needs and creating products that meet these needs, has become crucial for OEMs. PD makes it possible to capture and retain market share, to increase profitability, to cope with shortening product life cycles, to respond to shifts in expectations of customers and legislation, and to maintain competitiveness of mature products (Tidd & Bessant, 2018). An OEM's approach to PD can be a source of competitive advantage if they possess integrative capabilities that aim at minimizing functional or divisional silos within an organization. The usage of integrative structures during PD is also referred to as integrated product development (IPD) (Andreasen & Hein, 1987). In an IPD environment, individuals from various corners of the organization should come together to coordinate activities related to product-, production system-, and supply chain design (SCD) (Fine, 1998). During the last decades, scholars especially started to recognize the importance of performing SCD activities when developing new products (e.g., Fine et al, 2005; Hilletofth et al, 2018). SCD activities typically relate to the supplier base, transportation network, manufacturing footprint, storage points (e.g., warehouses, distribution centers), design of the materials flows (including its planning and control), plant globalization or localization, internal or external sourcing, and collaboration and

information sharing (Chandra & Grabis, 2007; Chopra & Meindl, 2007; Melnyk et al, 2014; Sabri et al, 2018). The purpose of this research is to provide a state-of-the-art overview of the SCD activities an OEM can perform when developing new products by systematically reviewing the literature.

The remainder of this paper is structured as follows: First, the research method is explained in Section two, second, the content analysis of the literature is presented in Section three, and last, the research is concluded in Section four.

2. METHOD

The purpose of this research is realized by systematically and critically reviewing relevant published peer-reviewed journal articles written in English. To overcome substantial challenges related to knowledge development due to differing theoretical views that influence how findings concerning certain phenomena are interpreted, this systematic literature review (SLR) follows the steps proposed by Durach et al (2017). These steps are defined and executed as follows:

1. *Define a purpose and/or research question:* The purpose is to identify the SCD activities that can be performed by an OEM during PD projects.
2. *Craft inclusion/exclusion criteria:* Only include English peer reviewed journal articles that propose SCD activities that can be performed during PD projects.
3. *Retrieve a baseline sample of potentially relevant articles:* In February 2018, search strings that contained keywords such as "concurrent engineering" "(integrated) product development" "logistics" "supply chain design" "procurement" were used within the databases ISI Web of Science, Scopus, and EBSCOhost. This resulted in the identification of 2566 unique articles and database alerts were set to also cover the remaining months of 2018.
4. *Apply the inclusion/exclusion criteria from step 2:* Two researchers individually applied the inclusion criterion and, where disagreement occurred, a third researcher was involved. This resulted in an initial sample of 70 articles. 9 articles were added from alerts, and snowball sampling resulted in 14 additional articles. In total, the synthesis sample consists of 93 articles.
5. *Synthesize the articles:* Emergent thematic coding is applied during the extraction of relevant data from the articles. Three researchers continuously interacted with each other during this step to ensure uniformity of the analysis.
6. *Report the results of the SLR:* The content analysis of the articles is discussed in Section three. This discussion is thematic in nature and outlines the knowledge gained during the synthesis of the final sample by using a subset of articles (47) from the synthesis sample.

3. CONTENT ANALYSIS

3.1 Strategy level activities

3.1.1 The balance of forecast and demand driven activities

An OEM also needs to find a balance between forecast and demand driven activities in the supply chain by positioning the customer order decoupling point (CODP) in the product fulfillment process during PD. The location where customization is performed in the supply chain affects how an OEM balances the levels of inventory and service (Lee et al, 1993). CODP placement should not harm the intended product functionality and should realize appropriate lead times and optimally allocate inventory to minimize manufacturing cost (Kristianto et al, 2012). The position of the CODP is affected by the type of manufacturing process (e.g., make-to-stock, make-to-order, configure-to-order). In a configure-to-order (CTO) environment, the inventory can be held in the module form, which makes the module the CODP of the total supply chain (Lee & Sasser, 1995). Hsu and Wang (2004) explain that, even though redesigning the products or processes may require extra investment to arrange the common parts for use in some of these products, there is a great advantage to risk-pooling effects. For example, delaying customization to a later stage in the supply chain may increase the OEM's flexibility to respond to changes in the mix of demands from different market segments. Next to being able to improve its responsiveness to orders, an OEM can reduce its inventory investments (Lee et al, 1993).

3.1.2 The balance of internal and external sourcing

During PD projects, an OEM should determine the balance between internal and external sourcing by prioritizing the areas they will spend internal resources on. First, this activity answers the 'make or buy' question for every item (e.g., raw material, component, subsystem) in the product design. Two classes of items can be roughly distinguished for every single product item: an in-house made item (make) or an outsourced item (buy). Second, this activity entails an OEM determining whether certain workloads associated with in-house made product items will be located internally or subcontracted to suppliers. How this activity should be performed depends on the product under development. For example, Primus (2017) proposes that outsourcing can be an option when developing a high clock-speed product if its design is highly modular. Additionally, if an OEM has the possibility to outsource manufacturing of items to low cost suppliers, then a highly modular design facilitates the outsourcing of a larger proportion of the production at a low cost. This ultimately reduces total supply chain costs (Nepal et al, 2011). Conversely, a high clock-speed product can be integral when an OEM is primarily responsible for realizing the product. However, outsourcing can be associated with an integral product design if the technical collaboration penalty is not too excessive and suppliers have superior PD capabilities (Ülkü & Schmidt, 2011). The balance between internal and external sourcing is further affected by competitive importance of an item within a product design (Noori & Georgescu, 2008). When an item is important for realizing competitive advantage, in-house manufacturing becomes favorable. However, when this type of item also has a fast clock-speed, a modular design can create conditions for outsourcing the manufacturing of these items to strategic suppliers. Outsourcing, however, can be difficult if there are issues related to intellectual property ownership. When the competitive importance of an item is relatively low and its clock-speed is fast, the balance between internal and external sourcing can be based on the OEM's capacity availability and on the supplier's capacity flexibility and capabilities.

3.1.3 The geographical sourcing location

Scholars further examine the ideal geographical location for internally or externally sourced product items or workloads. The product design influences the ideal geographical sourcing location. Therefore, the performance of geographically centralized and decentralized supply chains should be evaluated while considering all possible product designs. Krikke et al (2003) conclude that it is more cost efficient if an OEM and other members of the supply chain are located in close proximity to each other. Members of the supply chain should also be concentrated in one city or geographic region when a product design is integral (Fine et al, 2005). Hong et al (2018) add that, due to transportation being one of the main contributors to carbon emission, geographically centralized supply chain can significantly reduce the environmental impacts of a product design. When dealing with a modular product family, the negative implications of product variety on operational performance can be reduced when members of the supply chain are located in geographical proximity relative to each other (Salvador et al, 2002). For example, a centrally located and highly automated distribution center can reduce product and delivery lead times (Khan et al, 2012). Alternatively, members of the supply chain can be highly dispersed geographically when a product is modular. It is also possible to source from more distant locations when an OEM reduces product variety (Nielsen & Holmström, 1995). Pero et al (2010) conclude that innovative products are typically sourced from geographically dispersed sites (e.g., global sourcing), whereas less innovative products tend to be sourced from more central locations (e.g., local sourcing). Alternatively, global sourcing might work for basic product items and established technologies, whereas local sourcing can make testing and initial production easier and faster (van Hoek & Chapman, 2007).

3.1.4 The balance of single and multiple sourcing

Scholars also discuss how the balance between single and multiple sourcing can be determined during PD. When sourcing internally, an OEM must compare the costs and benefits obtained by the use of economies of scale associated with a single facility (e.g., manufacturing plant, warehouse, distribution center) against the costs and benefits of multiple facilities (Dowlatshahi, 1996). A comparison can be made based on aspects such as transportation costs, availability of transportation modes, an OEM's ability to provide speedy and reliable deliveries and services, and the ability of members in the supply chain to timely supply product (items). Krikke et al (2003) conclude that it is more cost efficient to use a limited number of facilities due to economies of scale lowering the fixed costs per unit. When there is a high level of product variety and retailers are being used, lead times and cost can be reduced by limiting the number of retailers (Thonemann & Bradley, 2002). When sourcing externally, single sourcing can be applied when OEMs procure product items from suppliers that are inexpensive to buy and store (Claypool et al, 2014). Additionally, single or limited sourcing is typically affiliated with products that have a relatively high level of quality and innovativeness (Di Benedetto et al, 2003). A main driver for this specific sourcing mode is the optimization of the strategic size of the supply base. For example, reducing the size of the supply base facilitates better rates, services, and genuine long- term relationships with the remaining suppliers.

3.1.5 Determining the type of supplier collaboration

Suppliers can be made responsible for varying kinds of workloads and integrated at varying phases of the PD process (Wynstra et al, 1999; Wynstra et al, 2003). The extent to which an OEM collaborate with individual suppliers during PD depends on the characteristics of outsourced workloads. For example, a low level of collaboration is needed when outsourcing workloads that are associated with highly modular products (Fine et al, 2005). This means that an OEM and suppliers may be highly dispersed culturally, have few close organizational ties, and have modest electronic connectivity. This type of suppliers does not have such a deep influence on the PD process. The need for vertical integration is reduced due to modularization facilitating the relocation of value-adding activities in the supply chain (Pero et al, 2010). Additionally, the required remaining interaction between an OEM and suppliers improves due to modularity reducing communication barriers. It becomes possible to communicate more frequently, clearly, and with less effort (Droge et al, 2012). For example, an OEM and suppliers can relate feedback to a specific aspect of the product or process when discussing product or process improvements. Furthermore, the level of trust with suppliers can increase due to pooling effects improving forecasts. Product modularity does make OEMs more dependent on suppliers (Nepal et al, 2012). Modularity reduces the negative implications of product variety on operational performance by minimizing the overall number of component families within the final product (Salvador et al, 2002). However, to achieve this, an OEM needs the help of knowledgeable suppliers to modularize the allocated design. For example, suppliers can help structure the organization of employees for different PD tasks and teams (Ye et al, 2018). A higher level of collaboration with suppliers is needed when an OEM outsources workloads associated with a product typified by high levels of integrality, quality, variety, or innovativeness (Di Benedetto et al, 2003). For example, Aoki and Staeblein (2018) describe that the heavily integrated design of automobiles makes it vital that an OEM collaborates with suppliers responsible for designing and developing large and complex product items. When externally sourcing a workload that calls for vertical integration, an OEM can organize close collaboration with suppliers in several ways. For example, an OEM and suppliers can be linked electronically, have a common business and social culture, and have a common or interlocking ownership when a product design is integral (Fine et al, 2005). Noori and Georgescu (2008) suggest that an OEM takes an equity position in a supplier when the competitive importance of an outsourced product item is strategic. For example, an OEM can create a new joint venture with a supplier and license-in the supplier's technologies to the new venture.

3.2 Network level activities

3.2.1 The capabilities and capacities of suppliers

The required capabilities and capacities of suppliers depend on the product under development. When products are of high quality and highly innovative, suppliers should match these characteristics. For example, when the competitive importance of an outsourced product item is high and have a fast clock-speed, suppliers should be able to innovate and be technologically capable (Di Benedetto et al, 2003). Alternatively, when product items have a low impact on competitive advantage and a fast clock-speed, supplier selection is an optimum decision between production costs and market mediation costs (Noori & Georgescu, 2008). Therefore, an OEM should closely watch and analyze the capacities and capabilities of suppliers available in national and international markets when designing a product (Wynstra et al, 2003). This may result in an OEM basing the design of new products on supplier capabilities instead of asking a supplier to supply certain products items. As a consequence, tolerances, parameters, features, and specifications can be changed, revised, or modified. For example, the physical dimensions of a product design can be determined based on the transportation mode(s) used by suppliers of transportation services (Dowlatshahi, 1996). Also, long lead time unique product items can be replaced with standard items through redesigning the product (van Hoek & Chapman, 2007). Using standard and simple product items results in an abundance of potential suppliers. Being able to choose from a large pool of suppliers makes it possible to reduce lead time times and product and inventory costs (Wynstra et al, 2003). Pero et al. (2010) propose that modularization of a product design makes it possible to reduce the number of suppliers needed by an OEM.

3.2.2 The capabilities and capacities of manufacturing plants

An OEM needs to determine its manufacturing footprint when sourcing workloads internally (e.g., Nepal et al, 2011). An OEM may be in a position that they can choose from a pool of potential proprietary manufacturing plants that offer different levels of service at different costs. Therefore, the manufacturing footprint can be determined based on a plethora of criteria, including capacity limits, cost, and lead time. Fixson (2005) stresses that this activity should be performed early during product design. For example, an OEM can assess where to locate production during the planning phase (Johansson, 2007). This activity can also be performed when the product design is listed in a BOM during the system-level design and/or detail design phase. Next to listing the quantities and performance levels of product items, a BOM should include the impacts of items on overall product cost, finished-goods manufacturing, overall throughput capacity, and key capital decisions (Pham & Yenradee, 2017). This makes it possible to consider the investment required to acquire (e.g., investment of land), build (e.g., installation cost), and maintain (e.g., production cost) infrastructure for any potential manufacturing plant during its life cycle. The BOM can be used to determine the number, location, capacity, and type of manufacturing plants based on their throughput limits (Yadav et al, 2011). Including this type of information in the BOM makes it possible to select manufacturing plants based on cost of goods sold and the inventory holding costs for safety stock and pipeline stock. Similarly, Arntzen et al (1995) propose a model that calculates at how many manufacturing plants a product (item) should be manufactured, where they should be located, and what technologies and capacities each should have. Elmaraghy and Mahmoudi (2009) formulate a BOM-based model that determines the optimal modular product design and manufacturing footprint while considering global market currency exchange rates and costs related to production, inventory, and transportation.

3.2.3 The capabilities and capacities of storage points

Before receiving product items or redistributing products to customers, retailers, or wholesalers, products are typically stocked in warehouses or distribution centers (Arntzen et al, 1995). An OEM can be responsible for this network of storage points in the supply chain. Therefore, they may need to determine the number, location, capacity, and degree of automation of these storage points during PD (Arntzen et al, 1995). This includes deciding which warehouse or distribution center serves which manufacturing plant or customer for each type of order and product.

3.3.4 The capabilities and capacities of the transportation network

The transportation network that supports the materials flow (i.e., inbound flow of product items, flow of WIP, outbound flow of products) in the supply chain also needs to be determined by an OEM. This includes assessing supply and distribution channels in terms of, for example, their length in distance and time (Fine, 2000). Additionally, transportation modes need to be selected based on, for example, their freight rate, traffic rate, shipment size, exchange rate, wage rate, and legal and ethical requirements (Dowlatshahi, 1999). The appropriateness of a mode also depends on the design of a product. For example, the transportability of a product is affected by a product's physical dimensions (e.g., height, length), dynamic limitations (e.g., acceleration, vibration), and hazardous effects (e.g., radiation, electrostatic) (Dowlatshahi, 1999).

3.3 Node level activities

3.3.1 The layout of the materials flow

Within a facility (i.e., manufacturing plant or storage point), an OEM needs to determine the flow of materials (i.e., WIP and product (item) flow) (Appelqvist et al, 2004). The layout of the materials flow depends on the facility layout, which constitutes the manufacturing processes, the storage areas, and the materials handling operations. First, the materials flow is mainly dependent on the layout of manufacturing processes (e.g., job shop or cellular). The ideal manufacturing process layout interrelates with the performance and functional specifications of the product's design (Fine, 2000). Different manufacturing process layout options can be evaluated to streamline the materials flow when, for example, setting or changing product geometries during a PD project (Appelqvist et al, 2004). The alternative manufacturing process layouts can be evaluated during the concept development phase in the PD process (Johansson, 2007). By the same token, products should be designed so they can flow through manufacturing processes in a speedy and efficient manner (Dowlatshahi, 1999). Johansson (2007) provides an example of an OEM assessing the number and size of work stations and the space available for the display of product items at these work stations during product and process development (i.e., system-level design or detail design) in the PD process. Second, the materials flow also depends on how various storage areas within a facility are connected with each other (Johansson & Johansson, 2006). Third and last, the flow of materials interrelates with the layout of materials handling equipment (e.g., circular, single-row, or multi-row). Lee (2001) proposes that within a certain equipment layout, product items should be routed based on how their associated geometric features, dimensions, tolerances, materials, and processes impact the precedence constraints of each item (or among items).

3.3.2 The capabilities and capacities of storage areas

The areas within a facility where product items provided by suppliers can be stored before being fed to work stations, where point-of-use storage and WIP is held, and where products are transported to customers need to be determined as well (Johansson, 2007). This includes determining the principles (e.g., FIFO/LIFO, dedicated/not dedicated), layout, and capacity of each of these storage areas. Several storage areas may be needed for locating point-of-use storage and WIP inventory within a production area (Johansson & Johansson, 2006). Outside of the production area, additional separate storage areas may be needed to hold WIP and product inventory. Johansson (2007) explains that room may need to be made within these storage areas for new product items and products during the design phase (e.g., system-level design or detail design) in the PD process.

3.3.3 The capabilities and capacities of materials handling equipment

The equipment (e.g., stations and forklifts) for handling (i.e., moving, storing, packing) materials within a facility can be selected and evaluated based on, for example, their degree of automation, cost, and load/unload capacity (Atmani & Dutta, 1996). The location and requirements of handling stations can be determined during the PD phases where product and processes are developed (i.e., system-level design or detail design) (Johansson, 2007). The appropriateness and the number of handling equipment needed is impacted by product characteristics such as tolerances, quantities, future redesigns, weight, size, and dimensions (Dowlatshahi, 1999). Therefore, the handling requirements of new products should be calculated. For example, Johansson (2007) states that equipment needed to stack product items at work stations can be evaluated during product and process development (i.e., system-level design or detail design) in the PD process. Lee (2001) goes one step further by proposing a model that simultaneously decides upon the layout of handling equipment and the design of a product. This model creates a layout by considering the type of handling equipment used. For example, a material handling robot imposes a circular layout, while an automated guided vehicle imposes a linear single-row layout or multi-row machine layout.

3.3.4 The capabilities and capacities of packaging

The packaging for inbound product items, WIP, and outbound products needs to be determined in terms of, for example, its physical dimensions, strength, shape, ease of handling, materials, transportation efficiency, and cost (Dowlatshahi, 1999). Simms and Trott (2014) advocate that existing packaging formats and technologies should be used where possible. However, a determination needs to be made regarding whether there is a need for new or special packaging. For example, special packaging may be needed within standard pallets and containers when inbound product items are sensitive and in risk of being damaged (Johansson & Johansson, 2006). Thus, the type of packaging needed is dependent on the design of a product and there may be a need to develop new and improved product specifications (e.g., reduced sensitivity) by redesigning parts more effectively (Dowlatshahi, 1996). Packaging design can be considered throughout the entire PD process (Bramklev, 2010).

3.4 Planning level activities

3.4.1 The forecasting of demand

An OEM needs to forecast the number of products requested by customers at a particular time interval so that products can be delivered reliably and timely (Pham & Yenradee, 2017). Johansson (2007) describes that the required production volume can be estimated during the planning phase. Scholars explain that demand affects the ideal design of a product. For example, products can have a high level of variety when the number of products requested by customers is low during a certain horizon (Thonemann & Bradley, 2002). In this scenario, supply chain performance can be improved due to reduced lead time and cost. Other aspects such as demand variability, forecast error, and product seasonality should also be known when designing products in terms of design lead times, product cost, and time to market (Dowlatshahi, 1996). Demand forecasts need to be continuously updated in, for example, an ERP system and translated to the overall capacity plan (Johansson & Johansson, 2006). Scholars tend to solely examine how an OEM can identify demand for the new product under development. However, an OEM needs to find out when only a current product is in demand, periods when both current and new products are in demand, and periods when only a new product is in demand in the marketplace (Jafarian & Bashiri, 2014).

3.4.2 The management of inventory

During a PD project, inventory can be managed in the supply chain by setting up and maintaining a system (e.g., ERP system) (Appelqvist et al, 2004). How inventory is managed depends on the design of a product. The OEM's supply chain should be geared towards small batches when a product is modular, has a low strategic importance, or has a high clock-speed (Noori and Georgescu, 2008). Alternatively, when a product ranks high on the competitive importance and on the clock-speed scale, the physical efficiency of JIT models should be combined with the responsiveness dictated by the product (Noori & Georgescu, 2008). Additionally, a modular product matches with decentralization of safety stocks (Elmaraghy & Mahmoudi, 2009). In a CTO environment, product modularization enables allocation of module inventory to several nodes in an OEM's supply chain (Lee & Sasser, 1995). Next to being able to improve its responsiveness to orders, decentralization of stocks enables an OEM to reduce its investment in inventory (Lee et al, 1993). Lower inventory levels at facilities are needed and there is less of a need to correct for stock imbalances between facilities (Lee & Sasser, 1995). This means that even though modularization of products may require extra investment to arrange the common parts for use in some of these products, there is a great advantage to risk-pooling effects (Hsu & Wang, 2004). A more decentralized inventory policy and product modularization is especially appropriate when a new market trend makes customer satisfaction an OEM's main objective (Elmaraghy & Mahmoudi, 2009). Furthermore, since product (item) lead time for a certain node in the supply chain is dependent on the inventory level of that node, the available inventory needs to be considered when designing a product (Wang & Shu, 2007). Dowlatshahi (1996) adds that a stable and robust product design reduces the inventory levels due to increased efficiency in manufacturing operations (e.g., reduced set-up time, predictable and stable lead times, faster throughput time).

3.4.3 The planning of capacity

Capacity planning is the process of an OEM determining the size and location of capacity in the supply chain based on a given service level (Arntzen et al, 1995). Capacity planning entails determining the product quantities that need to be processed by an OEM based on, for example, capacity restrictions (Appelqvist et al, 2004). How capacity decisions are made depends on product design characteristics. The OEM's supply chain should be geared towards capacity planning flexibility and reliable and fast logistics when a product is modular, has a low strategic importance, or has a high clock-speed (Noori & Georgescu, 2008). When a product is of strategic importance to an OEM, capacity decisions need to carefully consider the overall planning objectives in the determined horizon(s) and strategic business goals. Capacity planning is also influenced by the manufacturing characteristics of a product, which include lead times, set-up time, throughput time, and the length/size of the production run (Dowlatshahi, 1996). Planning of transportation capacity is also discussed and the transportation capacity of materials to and from an OEM's facility can be planned based on a given service level as early as possible during PD projects (Fixson, 2005). While planning outbound transportation, an OEM should consider how fast products should be delivered at customers (van Hoek & Chapman, 2007).

4. CONCLUSIONS

This research provides an overview of the SCD activities an OEM can perform when developing new products by systematically reviewing the literature. A total of 17 activities are identified, which can be divided over the following four levels: strategy, network, node, and planning. First, the strategy level activities relate to an OEM's sourcing and procurement strategy. These activities aim at determining what workloads an OEM will take care of internally, and what type of collaboration an OEM wants with suppliers when externally sourcing workloads. Second, the network level activities relate to the supply base, manufacturing footprint, and storage points of an OEM. In this context, a supply chain can be modelled as a network where nodes represent members of the supply chain. There are three types of nodes that can be managed by an OEM: supplier nodes, proprietary manufacturing nodes and storage nodes. The nodes are interlinked, which refers to the transportation network an OEM creates with other members in its supply chain in order to manage the flow and quality of inputs from suppliers into their facilities and outputs from their facilities to customers. Third, the node level activities concern the flow of materials within a facility (e.g., storage point, manufacturing plant). This includes the design of storage areas and selection of materials handling equipment and packaging. Fourth and finally, the planning level activities determine how materials and capacities are planned and managed based on customer demand.

5. REFERENCES

Andreasen, M., & Hein, L. (1987). Integrated Product Development, edited by Springer Verlag. *Berlin, Germany*.

Aoki, K., & Staeblein, T. (2018). Monozukuri capability and dynamic product variety: An analysis of the design-manufacturing interface at Japanese and German automakers. *Technovation, 70*, 33-45.

Appelqvist, P., Lehtonen, J. M., & Kokkonen, J. (2004). Modelling in product and supply chain design: Literature survey and case study. *Journal of Manufacturing Technology Management, 15*(7), 675-685.

Arntzen, B. C., Brown, G. G., Harrison, T. P., & Trafton, L. L. (1995). Global supply chain management at Digital Equipment Corporation. *Interfaces, 25*(1), 69-93.

Atmani, A., & Dutta, S. P. (1996). Product design and materials handling system selection - A concurrent engineering approach. *International Journal of Industrial Engineering : Theory Applications and Practice, 3*(1), 40-50.

Blackhurst, J., Wu, T., & O'Grady, P. (2005). PCDM: A decision support modeling methodology for supply chain, product and process design decisions. *Journal of Operations Management, 23*(3-4), 325-343.

Bramklev, C. (2010). A survey on the integration of product and package development.
International Journal of Manufacturing Technology and Management, 19(3-4), 258-278.

Chandra, C., & Grabis, J. (2007). *Supply Chain Configuration: Concepts, Solutions, and Applications*: Springer.

Chopra, S., & Meindl, P. (2007). Supply Chain Management: Strategy, planning & operation: Pearson Education Limited.

Claypool, E., Norman, B. A., & Needy, K. L. (2014). Modeling risk in a Design for Supply Chain problem. *Computers and Industrial Engineering, 78*, 44-54.

Di Benedetto, C. A., Calantone, R. J., VanAllen, E., & Montoya-Weiss, M. M. (2003). Purchasing joins the NPD team. *Research Technology Management, 46*(4), 45-51.

Dowlatshahi, S. (1996). The role of logistics in concurrent engineering. *International Journal of Production Economics, 44*(3), 189-199.

Dowlatshahi, S. (1999). Modeling approach to logistics in concurrent engineering. *European Journal of Operational Research, 115*(1), 59-76.

Droge, C., Vickery, S. K., & Jacobs, M. A. (2012). Does supply chain integration mediate the relationships between product/process strategy and service performance? An empirical study. *International Journal of Production Economics, 137*(2), 250-262.

Durach, C. F., Kembro, J., & Wieland, A. (2017). A new paradigm for systematic literature reviews in supply chain management. *Journal of Supply Chain Management, 53*(4), 67-85.

Elmaraghy, H. A., & Mahmoudi, N. (2009). Concurrent design of product modules structure and global supply chain configurations. *International Journal of Computer Integrated Manufacturing, 22*(6), 483-493.

Fine, C. H. (1998). *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*. Massachusetts: Perseus Books Reading.

Fine, C. H. (2000). Clockspeed-Based Strategies for Supply Chain Design. *Production and Operations Management, 9*(3), 213-221.

Fine, C. H., Golany, B., & Naseraldin, H. (2005). Modeling tradeoffs in three-dimensional concurrent engineering: A goal programming approach. *Journal of Operations Management, 23*(3-4), 389-403.

Fixson, S. K. (2005). Product architecture assessment: A tool to link product, process, and supply chain design decisions. *Journal of Operations Management, 23*(3-4), 345-369.

Hilletofth, P., & Eriksson, D. (2011). Coordinating new product development with supply chain management. *Industrial Management and Data Systems, 111*(2), 264-281.

Hilletofth, P., Reitsma, E., & Eriksson, D. (2018). Coordination of New Product Development and Supply Chain Management *Innovation and Supply Chain Management* (pp. 33-50): Springer.

Hong, I.-H., Su, J. C., Chu, C.-H., & Yen, C.-Y. (2018). Decentralized decision framework to coordinate product design and supply chain decisions: Evaluating tradeoffs between cost and carbon emission. *Journal of Cleaner Production, 204*, 107-116.

Hsu, H.-M., & Wang, W.-P. (2004). Dynamic programming for delayed product differentiation. *European Journal of Operational Research, 156*(1), 183.

Jafarian, M., & Bashiri, M. (2014). Supply chain dynamic configuration as a result of new product development. *Applied Mathematical Modelling, 38*(3), 1133-1146.

Johansson, E. (2007). Towards a design process for materials supply systems. *International Journal of Operations & Production Management, 27*(4), 388-408.

Johansson, E., & Johansson, M. I. (2006). Materials supply systems design in product development projects. *International Journal of Operations and Production Management, 26*(4), 371-393.

Khan, O., Christopher, M., & Creazza, A. (2012). Aligning product design with the supply chain: a case study. *Supply Chain Management: An International Journal, 17*(3), 323-336.

Krikke, H., Bloemhof-Ruwaard, J., & Van Wassenhove, L. N. (2003). Concurrent product and closed-loop supply chain design with an application to refrigerators. *International Journal of Production Research, 41*(16), 3689-3719.

Kristianto, Y., Gunasekaran, A., Helo, P., & Sandhu, M. (2012). A decision support system for integrating manufacturing and product design into the reconfiguration of the supply chain networks. *Decision Support Systems, 52*(4), 790-801.

Lee, G. H. (2001). Design of components and layout of machines for material handling. *International Journal of Advanced Manufacturing Technology, 17*(5), 371-382.

Lee, H. L., Billington, C., & Carter, B. (1993). Hewlett-Packard Gains Control of Inventory and Service through Design for Localization. *Interfaces, 23*(4), 1-11.

Lee, H. L., & Sasser, M. M. (1995). Product universality and design for supply chain management.

Production Planning & Control, 6(3), 270.
Melnyk, S. A., Narasimhan, R., & DeCampos, H. A. (2014). *Supply Chain Design: Issues, Challenges, Frameworks and Solutions*: Taylor and Francis.
Nepal, B., Monplaisir, L., & Famuyiwa, O. (2011). A multi-objective supply chain configuration model for new products. *International Journal of Production Research, 49*(23), 7107- 7134.
Nepal, B., Monplaisir, L., & Famuyiwa, O. (2012). Matching product architecture with supply chain design. *European Journal of Operational Research, 216*(2), 312-315.
Nielsen, N. P. H., & Holmström, J. (1995). Design for speed: a supply chain perspective on design for manufacturability. *Computer Integrated Manufacturing Systems, 8*(3), 223-228.
Noori, H., & Georgescu, D. (2008). Making supply chain design the rational differentiating characteristic of the OEMs. *International Journal of Production Research, 46*(10), 2765- 2783.
Pero, M., Abdelkafi, N., Sianesi, A., & Blecker, T. (2010). A framework for the alignment of new product development and supply chains. *Supply Chain Management, 15*(2), 115-128.
Pham, T., & Yenradee, P. (2017). Optimal supply chain network design with process network and BOM under uncertainties: A case study in toothbrush industry. *Computers & Industrial Engineering, 108*, 177-191.
Primus, D. J. (2017). A configuration and contingency analysis of the development chain. *Technovation, 64-65*, 1-15.
Sabri, Y., Micheli, G. J., & Nuur, C. (2018). Exploring the impact of innovation implementation on supply chain configuration. *Journal of Engineering and Technology Management, 49*, 60-75.
Salvador, F., Forza, C., & Rungtusanatham, M. (2002). Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management, 20*(5), 549-575.
Shamsuzzoha, A., & Helo, P. (2018). Virtual supply chain for networked business: perspective of collaborative bill-of-materials, scheduling and process monitoring for developing innovative product. *International Journal of Computer Integrated Manufacturing, 31*(6), 595-610.
Simms, C., & Trott, P. (2014). Conceptualising the management of packaging within new product development: A grounded investigation in the UK fast moving consumer goods industry. *European Journal of Marketing, 48*(11-12), 2009-2032.
Thonemann, U. W., & Bradley, J. R. (2002). The effect of product variety on supply-chain performance. *European Journal of Operational Research, 143*(3), 548-569.
Tidd, J., & Bessant, J. R. (2018). *Managing innovation: integrating technological, market and organizational change*: John Wiley & Sons.
Ülkü, S., & Schmidt, G. M. (2011). Matching product architecture and supply chain configuration. *Production and Operations Management, 20*(1), 16-31.
van Hoek, R., & Chapman, P. (2007). How to move supply chain beyond cleaning up after new product development. *Supply Chain Management: An International Journal, 12*(4), 239- 244.
Wang, J., & Shu, Y.-F. (2007). A possibilistic decision model for new product supply chain design. *European Journal of Operational Research, 177*(2), 1044-1061.
Wynstra, F., Van Weele, A., & Axelsson, B. (1999). Purchasing involvement in product development: A framework. *European Journal of Purchasing and Supply Management, 5*(3-4), 129-141.
Wynstra, F., Weggeman, M., & van Weele, A. (2003). Exploring purchasing integration in product development. *Industrial Marketing Management, 32*(1), 69-83.
Yadav, S. R., Mishra, N., Kumar, V., & Tiwari, M. K. (2011). A framework for designing robust supply chains considering product development issues. *International Journal of Production Research, 49*(20), 6065-6088.

Ye, Y., Huo, B., Zhang, M., Wang, B., & Zhao, X. (2018). The impact of modular designs on new product development outcomes: the moderating effect of supply chain involvement. *Supply Chain Management: An International Journal, 23*(5), 444-458.

Zhang, X., Huang, G. Q., & Rungtusanatham, M. J. (2008). Simultaneous configuration of platform products and manufacturing supply chains. *International Journal of Production Research, 46*(21), 6137-6162.