

A Review of New Product Development (NDP) in Sustainable Supply Chain Management (SSCM)

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Abstract

The dynamic growth of industry, driven by the emerging needs towards sustainable environment, has made multiple life cycle product into an important aspect in providing the result for efficient supply chain management from as early as the design stage. Due to these current needs, the focused is to provide it with a flexible framework to be implemented for various multiple life cycle products meant to be remanufactured. This paper explores the literature review carried out for sustainable supply chain management in new product development. It is also intended to strengthen the requirements for any new products, of which should be designed to incorporate the multiple life cycle identity. The objective has therefore been to develop a practicable framework that will be tested for identified any products and determine whether it is a requirement in the initial design of new product development. In summary, this research will provide a better perception and act as a guideline for new product development. The idea is innovative to assist product designers to collaborate with supply chain managers to retain the science of multiple life cycle products.

Keywords: Supply Chain Management, Sustainable Supply Chain Management, New Product Development and Product Lifecycle.

Introduction

Supply chain management (SCM) is involved in the process of product lifecycle consideration when developing new products for multiple lifecycle products (MLP). SCM for MLP is emphasised in this literature as the recent researches in sustainable supply chain management (SSCM) have highlighted on multiple lifecycle products, particularly for engineer-to-order (ETO) product manufacturing (Reefke & Sundaram, 2017). During planning stage strategic consideration will be required (Cooper *et al.*, 1997). Thus, it is beneficial to include SCM during NPD in order to establish that the product can sustain multiple lifecycle

duration as well as be able to pre-determine its MLP requirements. It is opportunistic to the industry for reducing and eliminating waste by employing the suitable SCM for MLP product during NPD.

In the industry of manufacturing, MLP are considered as high-value production of vehicle manufacturing machine. The production of this product will be conducted based on the economic plan or scale outlined for a certain customer's needs and necessity. It implies that the products worth at least a single lifecycle. In addition, in order to save cost and effectively achieve SSCM manufacturing target is to extend their lifecycle (Rajeev *et al.*, 2017).

There has been an increase of literature exploring the synchronization of existing theories pertaining to the perception of SSCM as well as on practices of NPD. Hence, the literature comprises of sustainable supply chain management, new product development elements and product lifecycle management.

Integrating Sustainable Supply Chain Management, Product Lifecycle Management and New Product Development.

Sustainable supply chain management (SSCM) can be defined as a tactical accomplishment of an organisation in terms of social, environmental and economic goals (Carter & Rogres, 2008). Carter & Rogers (2008) added that the goals are achieved in a systematic coordination key inter-organisational process, which enhances the economic performance of an individual as well as its supply chain in the long-term period. This concept is illustrated below.

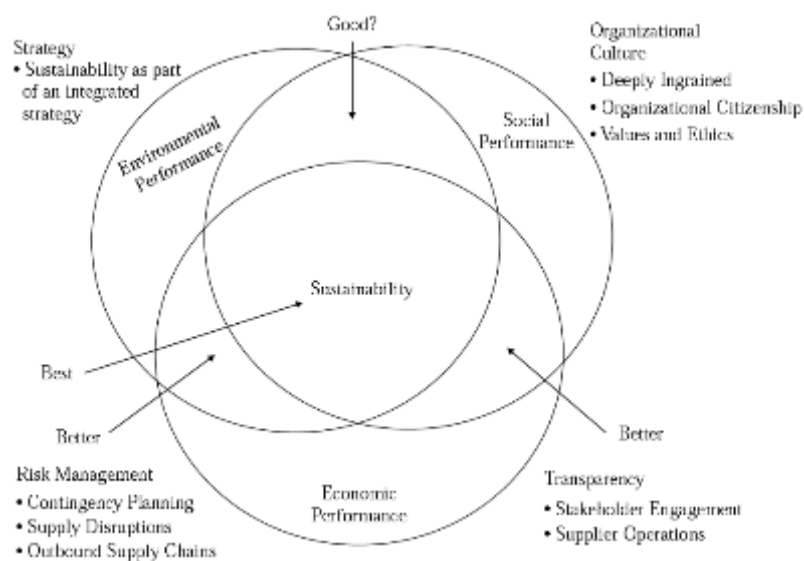


Figure 1: Sustainable Supply Chain Management (SSCM) (Carter & Rogers, 2008)

Based on Figure 1, a question mark was placed next to the term 'good', which marks the connection of components between social and environmental. However, it excludes the triple bottom line of the economic components due to the social and environmental dimensions of SSCM. In addition, it does not indicate that the organisation carelessly embarks on social and environmental goals concerning the supply chain. Some scholars perceive that environmental and social initiatives are expensive; hence the use of the question mark (Carter & Rogers, 2008).

Potential economic advantages (intersections of economic with social and/or environmental performance) in Figure 1 consist of the following:

- (1) Reduction of packaging waste leads to cost saving.
- (2) Health and safety, lower recruitment and labour cost are reduced causing a more secure warehousing and transportation, which will lead to better working conditions.
- (3) Low labour charge can cause a more effective working environment and increase motivation as well as production in which it can lessen the absenteeism of supply chain personnel.
- (4) Practically determining future regulation: environmental and social concerns needs to be positively addressed as it can influence government rules. The regulation is developed based on a company's existing production and supply chain process, which makes it challenging for other companies to replicate.
- (5) ISO 14000 standards, which consists of less cost, shorter lead times and finer quality of product provides a significant structure for environmental management systems.
- (6) Improved reputation: Appropriate attitudes can enhance an organisation in the eyes of the customers, suppliers and future employees.

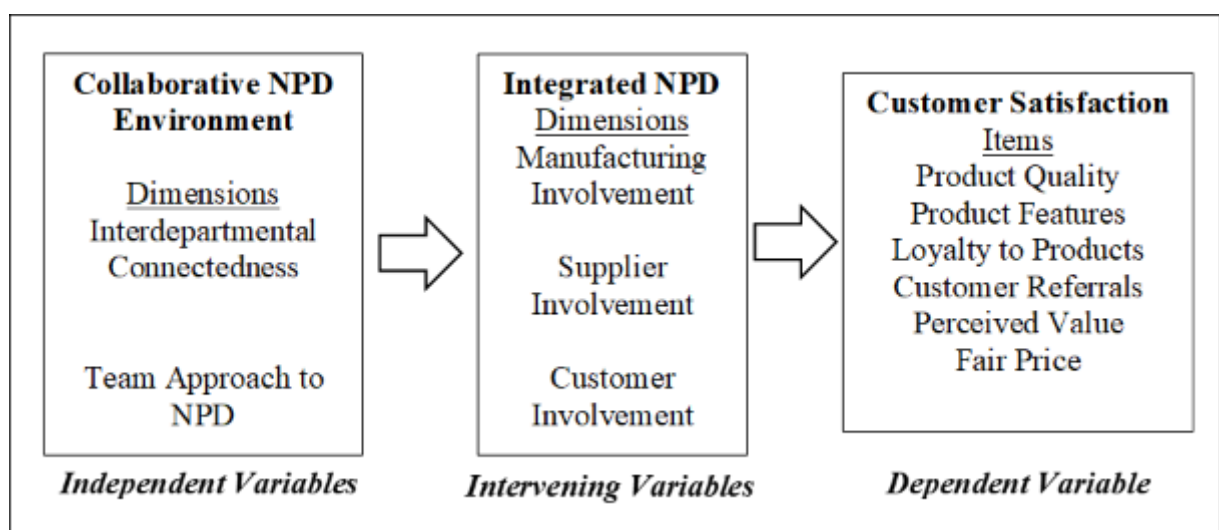


Figure 2: Explanatory and Theoretical Model to Link New Product Development (NPD) and Sustainable Supply Chain (SSC) (Tan & Tracey, 2007)

Furthermore, Tan & Tracy (2007) conducted a study and introduced an explanatory/theoretical model to link new product development with SSC. This model assists in conceptualising the association between independent variable and customer satisfaction, which is represented as the six distinguished measurement items. This model employed composite measures and path analysis that examine the effects of collaborative NPD environment when involved with one internal party (manufacturing), two external parties (suppliers and customers) and on customer satisfaction. Future researchers should conduct an investigation by expanding the model so that it contains more variables. For example, variable that can describe the contribution of other parties such as marketing, engineering

and R&D and also examine other outcome variables like the reduction of cost, time-to-market and firm performance.

Moreover, there has been insufficient research associating SCM with NPD, despite the fact that the product is designed with NPD tools and distributed with supply chain features (Hasan *et al.*, 2014). In addition, SCM is not always taken into account during new product development for multiple lifecycle products. Thus, it is vital that SCM is included during NPD so that it can manage multiple lifecycle durations. MLC requirement can also be established and developed ahead of time (Nasir *et al.*, 2016). In the past years, the coordination of SCM and NPD was widely studied by various researchers. The “demand” concept should be emphasised through the supply chain while it necessitates the NPD process as well as the research and development (R&D) entities to be in a close position within the manufacturing sector (Ganji *et al.*, 2017). New product development has been studied and the methods have been adopted to the supply chain. Critical-success-factor was also defined and employed in the frameworks to sustain supply chain. Additionally, risk and threats related with supply-chain restructuring as well as key benefits for connecting the concepts together were investigated.

Past researchers have indicated that SSCM is the main agenda among companies and businesses, yet it lacks the applicability as a holistic approach (Ansari & Kant, 2017). Nonetheless, there is inadequate study specifically in the literature reviews that is on the status of framework development in SSCM (Ansari & Kant, 2017). SSCM is when sustainability is incorporated in all business function in which it will cause a complex and cross-disciplinary field. Companies that are willing to instil sustainability practices in their supply chain needs to fulfil many challenging objectives; for example, profit maximization and social responsibility expansion. These issues indicates that the research on SSCM is still at a very early stage when integrating all three elements (social-economic-environment) (Ansari & Kant, 2017).

Company researchers created a theory that matches multiple concepts and present a framework to be analysed, while business practitioners impart the real practical implementation, in which Ansari & Kant (2017) devised an output. The framework is the base as it comes from the variables and creates certain predictions. However, its effectiveness is a main concern (Ansari & Kant, 2017). Numerous elements that determine the preparation of the framework can assist in effectively managing companies’ relationship. Nevertheless, SSCM framework conveys several numbers of constructs that form the foundation of the framework (Ansari & Kant, 2017).

In addition, Ansari & Kant (2017) discovered that in the Scopus database, 92 out of 349 articles reported on the framework. Many of these articles were not selected for the review process because of its inability to meet the required requirements of the above lists, even though the articles contain a conceptual model / framework (Ansari & Kant, 2017).

Büyükoğkan & Çifçi (2013) have classified findings from literatures on fundamental practices for sustainable supply chain management, which is acknowledged from the elements below:

- (1) Price Strategy: An important practice in traditional SC since its objective is to make suitable price for the product so that it can improve customers' satisfaction as well as profit.
- (2) Optimization of Supply Chain: For a sustainable supply chain. Optimization must be strategically conducted in terms of supply chain design and product design, in which both of these designs must be linked intrinsically. Examples include: transportation loads and routes, warehouse layout and logistic network design.
- (3) Inventory management: It is important that inventory is effective, and supply is steady. Excess and low inventory are due to poor management in the aspects of data, storage locations and order quantities.
- (4) Forecast accuracy: When accuracy of supply and demand forecast is increased, it can lessen the waste and other inventories related to the supply chain. For instance, supply chain visibility, customer service and responsiveness.
- (5) Lifecycle management: Evaluating product sustainability is significant in total product life-cycle.
- (6) Supplier management: Key procedures for supplier management includes; qualification, environmental and social problems and supporting suppliers.
- (7) Flexible and cleaner technology: Technologies are cleaner and natural resources are used more effectively. This will create product that have less harmful components and less pollutants. Goods can also be recycled.
- (8) Delivery performance: Following delivery schedule is vital. On time delivery and response for a competent supply chain.
- (9) Usage of effective systems and tools: It is important that SC design use its capacity effectively. For example; accounting systems, decision support and management tools.
- (10) Environmental management system: This includes environmental policies, implementations as well as certifications. ISO 14001 is the most commonly used environmental management system and was first initiated in 1996 then updated in 2004.
- (11) Green innovation: Research and development (R&D) strategies and activities that is specifically for eco-efficiency of products and technologies.
- (12) Environmental product design: Good products have minimal waste during the manufacturing process.
- (13) Environmental activity capability: This includes activities such as life recovers, reuse and recycle.
- (14) Efficient handling and storage: Highlights on safety measures that will care for workers' health and safety issues. Examples; environmental contamination from spills or leaks, higher insurance premiums and operational downtime.
- (15) Eco-friendly transportation: Transports that can move equipment safely, which uses fewer fossil fuels and operates on reusable materials.
- (16) Reverse logistics: Goods are moved back into the system and employed for other purposes.
- (17) Green and back packaging: To encourage safe and cost effective recovery by utilising reusable materials.
- (18) Collaboration with partners: A good relationship with collaborations or compliance must be developed.

- (19) Employee practices: Employees certification programme, education and precautions for measures are imperative to sustain SC design.
- (20) Outsourcing: Relationships with third parties can cause a reduction in cost, improve efficiency and customer satisfaction.
- (21) Stakeholders' rights: Protects stakeholder's right in terms of ethnic, care and loyalty.
- (22) Monitoring and maintenance: Companies should ensure that their suppliers act in a proper manner.

Based on previous literature, various researchers have defined sustainability from many perspectives as well as driving forces and purposes. Nonetheless, the most common structures found are pillars, namely economic, environmental and social.

- (1) Economical requirements: Advanced environmental management firm emerges, and the requirements include, quality improvement, cost reduction, and enhanced customer service. These factors will provide continuous benefits in the supply chain management.
- (2) Environmental requirements: the four important requirements are energy efficiency, waste reduction, and natural resource conservation and emission reduction. The practice is based on the firm's goal of integrating the environmental aspects so that it will lead to corporate survival.
- (3) Social requirements: It consists of four elements which includes health and safety, reduced impact on community, laws and regulations, and strengthened relationships. This is a response towards the government and the public to hinder industrial production on the environment. Thus, companies are taking the required steps to meet this measure and change their SC process.

Establishing the significance of customer requirement is a basic problem in quality function deployment applications. This is due to the fact that quality function relies on communicating efficiently with other team members and reflects each other's preferences.

Meanwhile, the difference between open loop and closed loop reverse supply chain is that returned products are usually returned to initial producers. In open loop reverse supply chain, the used product is not returned to the initial producers, instead it is taken by an outsider firms (Ene & Öztürk, 2014). Moreover, a reverse supply chain can either be closed-loop system or an open-loop system (Ene & Öztürk, 2014). In order to handle the reverse supply chain efficiently, network issue should be emphasised. Problem occurs when the network design determines the number and location of facilities and distinguish the flow of materials between the facilities (Ene & Öztürk, 2014). Each year, many research articles highlights the sustainable issues in the SC. Yet, the strategies that the authors employ to tackle these problems usually comprises of case-based studies, developing theoretical models, modelling problem, and building framework. It is essential that the number of studies from a sample is identified in order to design a framework. Hence, it is compulsory to build an understanding of the study and classify it as a framework (Ansari & Kant, 2017).

New Product Development

NPD is the key in improving product quality, which is much needed in today's competitive business scenes. It improves not only the quality but also consumer satisfaction, increase profits and long-term prosperity (Ganji *et al.*, 2017). Furthermore, the "demand" paradigm must be highlighted using the supply chain, in which the NPD process and research and development (R&D) is in a close position with the manufacturing sector (Ganji *et al.*, 2017). Ganji *et al.*, (2017) provided an example using Dreamliner, in which it allows researcher to investigate practices within the NPD process; for example, advantages, disadvantages. It also seeks to observe the opportunities for a manageable NPD approach, considering that significant manufacturing cases like Boeing Dreamliner had also experienced challenges during their product development stage and supply chain redesign.

The new product development (NPD) literature highlights the significance of presenting new product to the market as a mean for business success. Its contribution for the growth of the company is influence on the profits that it is able to obtain; thus, its role as a main factor in business planning. There are many responsibilities of new products for instance, economic growth, employment and standards of living. Therefore, it is beneficial that NPD and its emerging processes are investigated.

It is crucial to consider whether the products can be produced with the designate specification, materials and packaging. This implies that design is very important in the supply chain decision and it emphasis the needs for better design (Khan *et al.*, 2012). The literature has established the effect of modularity and variety on supply chain performance; yet, it did not take into account the impact of the innovativeness of the product (Pero *et al.*, 2010). In a case study conducted by (Pero *et al.*, 2010), it is clear that the variables need to be considered in order to correspond NPD with SCM decisions. In addition, when researching on the effects of NPD on the supply chain product modularity and variety are not the only significant variables.

The supply chain can be influenced by the product line newness level or degree of innovativeness, which is regulated during the product development. Not only that, other issues like operations issues can also affect the product development. Moreover, NPD is associated to many departments in the manufacturing enterprise and the design department defines the concept of the product so that it will meet the requirement of the customers. Manufacturing, on the other hand, is the engineering department that purchase materials and distributes the whole supply chain (Hasan *et al.*, 2014). Similarly, Bhuiyan (2011), believes that controlling the NPD process has become quite challenging, since it involves extensive financial and human resources and is time sensitive. Despite the various research on NPD success, companies still tend to produce failed products. Due to this, NPD is ranked as the riskiest task for the companies. Additionally, in terms of investments, when dollars increased for NPD investment then the pressure to exploit the returns also increases. 46 percent of resources assigned to NPD failed to provide sufficient returns(Bhuiyan, 2011).

Product Lifecycle

Product lifecycle consists of concepts, designs, manufacturing, processes and even to the shop floor. Multiple lifecycle product is when a company specialise in engineering develops a design of a product or components, this is known as *bill of material* (BOM). BOM is

described as resources and shop orders (Nasir *et al.*, 2016). During the early stage of the product lifecycle, the engineer is required to make an impactful decision on the supply chain, which is known as “make-or-buy”. Some industries tend to combine design with manufacturing practices, which will provide a firm control of the supply chain. In electronic fields, the supply chain is universal, and orchestration becomes crucial (Felic *et al.*, 2014).

Furthermore, in the aspect of design engineering, requirement engineering occurs at the initial stage of development. It does not only comprise of form, function and design fit, but also establishes the requirements that are needed to manufacture and produce the product. This includes all “what, who and where” of the whole process. It is one of the primary practices that control the important aspects of the supply chain. This is because, this stage will decide suitable products for the market requirement and how its design-process will be conducted; thus, making a link to the supply chain planning. Therefore, this stage is one of the crucial stages before a product is launched and it is also the key reason that causes company difficulty to meet the production schedule. A deficiency in the supply chain should really be prevented.

Changes in the features of the product design are due to modern technologies, which have caused improved productions of many products. When trends of product change, it will affect the number of disposal of obsolete product and precedes a shorter product lifecycle. Additionally, it will too affect supply chain by changing the design to many touch points. When components are unavailable it will cause a supply chain constraint, which means that the supply chain will need to ping the PLM system and appeal for new parts. Engineering design will be required to obtain the replacement.

Furthermore, there are many processes that lead to continuous improvements, since there are many analytical tools available. The changes can be affected in areas of manufacturing process or even as early as product design. Today, PLM system authorises designers to observe engineering drawings across companies. Suppliers are also involved in designing product and in some cases, it is the supplier that designs the product. In conclusion, manufacturer or suppliers needs to simultaneously agree with the requirement of the product, so that designers can proceed with the design process.

In close-loop PLM, the information is moved back and forth along the product lifecycle. The aim of this is to employ product embedded information technology with its information for the whole product lifecycle (Felic *et al.*, 2014). Based on the findings, the most appropriate elements for the development of new product were supply product lifecycle management, chain management, and new product development. All these factors are significant in expanding the SSCM framework. SSCM is a topic that is frequently discussed in recent years (Gosling *et al.*, 2017).

Examining product lifecycle management process in the setting of supply chain management, product lifecycle undergoes five specific stages. These stages are as follows:

- (1) Development stage of new product: The costly stage for the company. The enterprise will encounter insufficient sale and withstand a substantial loss that is as equal as the scale and complexity of the launched product.

- (2) Market stage introduction: In this stage, the product lifecycle is expensive with reasonably low volume and continual losses within the scale of effort.
- (3) The growth stage: This phase is indicated by a steady reduction of economies of scale with a slow increase of sale (presuming that the product is a success) arises and profit increases.
- (4) Stage of maturity: This stage is defined by extremely low costs. The sales of the product have reached the peak and reducing the price of the product due to competitive pressure could lead to a significant gain.
- (5) Decline stage: In this phase, it indicates a decrease in sales, prices and profit.

Basic elements of supply chain is reviewed and explained by SCOR model created by the Supply Chain Council's. It comprises of plan, source, make, deliver and deal with many forms of returns.

At each of the stages of the product's lifecycle, its practicality to the supply chain may differ. Below are the stages of lifecycle management:

- (1) Supply chain planning is vital during the new product stage. It is beneficial that the company realise the needs of the products tactically in terms of implementing all the supply chain elements and then advancing to a collaborative supply chain. It is considered threatening if the big picture is not yet secure. It is crucial the evaluation of resources is conducted repeatedly as the product takes its shape. For instance, changing from metal casting to plastic may lead to an alternation of the nature of supply to 180 degrees. The decision to switch from less computer memory to additional memory may provide positive or negative results. Comparably, by planning how the product will be produced will affect the customer's heart. Additionally, it is encouraged to plan the distribution process, recognition process and eventual return process.
- (2) The supply is operating and tuned during the market introduction stage. When supply chain is closely investigated, a company can bring the cost of their start up product into line. One of the benefits of low sales volume is that it provides a adaptable scale of sources, products and reaction that can be tracked. When the supply chain hits into gear, the growth stage will occur. The cost reduction from economies is due to lean look at manufacturing and distribution, sourcing and understanding of customer's reaction and feedback.
- (3) Customer feedback in terms of how effective a company delivers and maintains the product will result to a maintained growth. Increased sales volume can be achieved by employing the suitable logistic and assessing value to its customers.
- (4) The mature stage determines the success or failure of the company. Adhering significant resources, inbound logistic, warehousing, manufacturing practice, and evaluating customer's feedback will lead to low cost and impressive sales volumes. Companies that employ supply chain will have a greater advantage as a reduction in price can be offset by good supply chain turning; hence, a great profit can be experienced. However, a careless step in marketing or underestimating customers may cause a massive decline in sales.
- (5) Companies should not give up when facing with the decline stage. If the profit can still be reached, then the company should revise on practicality and highly oiled

supply chain. Great skills is required to balance both reduced and prices and lagging sales. However, by effectively utilising the supply chain strategy can balance be achieved. In addition, it is at this stage where a product is given a chance to be renewed.

In the other side of the coin, reverse supply chain differs from supply chain as it needs to first be disassemble and put in storage before the arrival of customer demand. In addition, its cores return to an intermediate state which is known as push-pull boundary. It can also be described as a delayed differentiation in a forward supply chain that necessitates a remanufacturer disassemble for it to return to a semi-complete product and delay customer differentiation. In the reverse supply chain, a delayed differentiation requires that a return and delay for a final customer differentiation. When the demand arrives, forward and reverse supply chains integrate together the required demands, which includes software, components, and materials or other things that will meet the customer's specific demand in the pull phase (Abbey *et al.*, 2013). In order to address the differentiation issues, Abbey *et al.* (2013) displayed an extensive motivation on various on-site visits as well as explained numerous scenarios that assess the ramifications for the evolution of the delayed differentiation choices. Abbey *et al.* (2013) added that there is a huge dissimilarity between remanufacturing operations and regular manufacturing operations because remanufacturing input can be non-standard, and the quality and supply may be ambiguous.

Multiple Lifecycle

Design for Upgradability (DfU) was established by (Aziz *et al.*, 2016). It is a form of remanufacturing strategies that prolongs a product lifetime, which is an efficient development of the product. Multiple lifecycle products are modelled with easy upgradable features that grant the product to be upgraded if the product is not functioning well or become out-dated. Previous researches in this area have focused on design features and characteristics of upgrading. Nevertheless, there are limited studies focusing on how DfU can be implemented in the process of product design integrating modelling and optimization process. This research has provided a detailed description of works presented by previous researchers that have contributed on design upgradability. In addition, a review of modelling and optimization methods that are frequently used for corresponding design alternatives are also discussed and analysed in terms of practicality as tools to select the greatest upgradable product design (Dubey *et al.*, 2017). It is suggested required for further research emphasising on the tools needed to enhance design upgradability and its importance development of product for multiple life cycles.

A vital strategy in the developing products is the concept of the multiple lifecycle, since it is one of the options in creating a more sustainable product (Aziz *et al.*, 2016). This is because it illustrates interconnection of the product components, which is deemed significant for manufacturer as well as designers when dealing with modular structures and multiple life products (Aziz *et al.*, 2016). In addition, multiple lifecycle product is considered as a solution for sustainable manufacturing model; for example, "take-make-dispose". It allows the product to possess multiple lifecycle that maximise the usage of raw materials and minimise energy consumption as well as recapture the most extreme value-added such as inputs in terms of plant, labour and equipment (Ye *et al.*, 2014).

Moreover, multiple lifecycle products signifies that the product is initiated to be used multiple times to alter the existing resource-consuming manufacturing model into resource-conservation manufacturing model (Ye *et al.*, 2014). In addition, Product Lifecycle Management (PLM) emphasise on managing data and process of product in their lifecycle stages (Felic *et al.*, 2014). This can be observed as an arrangement of methodologies that can administer product information and processes of the whole product lifecycle (Felic *et al.*, 2014).

The advantages that can be predicted from Product Lifecycle Management includes enhance quality of the product, lessen time-to-market and reduce the cost of the products. Many efforts have been made to ensure that there are solutions for collaborative product development. Many of which focuses on collaboration of partners that influences a certain process in product lifecycle management (Felic *et al.*, 2014).

Presently, regular changes and adjustments in technologies are normal standard for multiple products such as semiconductor fabrication equipment, imaging equipment, and jet turbine engines (Abbey *et al.*, 2013). When remanufacturing is referred to as multiple lifecycle product, many literatures were found to be related. Companies, for instance, GE Transportation, Cummins diesel engines, and Xerox highspeed imaging equipment allows simple updates to enhance performance (Abbey *et al.*, 2013). The mentioned companies utilise remanufacturing to recover the sizeable value remaining in end-of-lease or end-of-use product returns (Abbey *et al.*, 2013). Additionally, modular upgrades can drastically lessen the material usage as well as labour inputs while at the same time improve the overall environmental performance (Abbey *et al.*, 2013). Furthermore, remanufacturing can also be somewhat profitable and provide adequate benefits to the environment due to the recued material used and energy consumption (Lund & Hauser, 2010). This is the advantages that countless OEMs desire.

Conclusion

Most researchers have tried to bridge this gap by designing a framework that indicates the interrelationships of numerous elements, which resulted to finding a basic structure for concept development (Ansari & Kant, 2017). The success and profitability of supply chain can be due to the expanded knowledge in this area of research (Ansari & Kant, 2017). There are three kinds of sustainable supply chain management strategies; proactive, reactive and anticipate. These strategies have been distinguished in in this current review and are based on four different dimensions; namely, supply chain leadership, SSCM governance, supply chain learning, supply chain risk management, and SSCM performance (Gosling *et al.*, 2017). These strategies can distinguish important success factors of SSCM. Moreover, items that are produced with extended life can improve supply volume and flexibility, which meet the needs of a sustainably produced product (Gosling *et al.*, 2017). Furthermore, NPD-SCM alignment has no comprehensive framework and the management practice require instruments that can explain the effects of presenting new products on the supply chain (Ho *et al.*, 2015). The tool should be able to provide guidelines to managers and enable them to distinguish decisions that can cause high performance. Therefore, as a summary in this literature review, there is a lack of study of sustainable supply chain management in multiple lifecycle in new product development.

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