Chapter 5

Managerial Best Practices to Promote Sustainable Supply Chain Management & New Product Development

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Additional information is available at the end of the chapter

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1. Introduction

Supply chain management is the integration of the activities that procure materials, transform them into intermediate goods and final products, and deliver them to customers [1]. New product development (NPD) processes include design and development along with sourcing through the company's development chain. In order to remain competitive, supply chains must continuously develop and deliver new products and services to the marketplace (e.g. [2-7]). Carefully matching the product characteristics to the appropriate supply chain strategy is critical to being competitive [8] and to aligning appropriate order winners and order qualifiers with customer requirements [9].

Sustainability is a new trend in Supply Chain Management and is a conceptual framework for aligning the 'triple bottom line'-environmental, social and economic dimensions [10]. Environmental sustainability is the most recognized dimension as corporations seek to reduce the natural resource consumption below the natural reproduction in both the processes and products its produces. Environmental considerations include global warming, which can be attributed to 6 greenhouse gases (like carbon dioxide, methane and nitrous oxide), and pollution. In the United States, since industrial activities account for about a third of carbon dioxide emissions and 40% occur due to transportation, supply chain activities are a primary factor in environmental sustainability [11]. Economic sustainability refers to the profitability of the sustainable efforts. Without economic sustainability, businesses will cease to exist, and this aspect becomes an order qualifier for any product. Social sustainability can be divided into both internal and external dimensions. Internal social sustainability refers to the motivation, skills and loyalty of employees and business partners in the supply chain, while external

social sustainability refers to the value that is added to the community that the company operates in. Social sustainability is the least researched and developed dimension in NPD [12-14]. In fact, the social aspect is the least research and developed dimension in sustainability as a whole, and the social and ethical dimensions have not been given the same attention by businesses since the measurable results are less tangible [15]. Many business theories view these three dimensions as trade-offs and not necessarily 'win-win' situations. For example, environmental regulations provide social benefits; however, private costs for prevention and clean-up increase, which reduces competitiveness [16]. However, proactively, pollution prevention through product and process design is viewed as superior and more economical to pollution control through waste management [16].

Why sustainability now? Business leaders are confronting resource depletion, recognizing new roles for businesses in economic and social change, and responding to stakeholder demands (e.g. Government, employees, shareholders, environmental groups, nongovernmental organizations (NGOs), and citizens) for information and accountability [17]. Going green can save money and open new revenue streams [18]. Growing pressures exist from government and society to deal with factors contributing to global warming, raw material scarcity, and deterioration of human rights [19]. Other motivations come from consumer's concerns, intrinsic motivations of the companies or legal requirements [14]. Government policy and regulations as well as Corporate Sustainability policy may be the initial drivers for sustainability [20].

Sustainable Supply Chain Management (SSCM) can be defined as "the strategic, transparent integration and achievement of an organisation's social, environmental and economic goals in the systemic coordination of key inter-organisational business processes for improving the long term economic performance of the individual company and its supply chains" [21 p.368]. Sustainable development is grounded in the Brundtland Commission's definition as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [22 p. 43]. SSCM allows companies to maintain control over their supply chain and potentially achieve competitive advantages through enhancing track and traceability from raw materials through to the customer [14]. SSCM can be defined as the management of material, information and capital flows as well as cooperation among companies along the supply chain while addressing goals from all three dimensions of sustainable development (economic, environmental and social) which are derived from customer and stakeholder requirements [23]. Companies can gain competitive advantage through sustainability [24], which in turn affects the whole supply chain [25]. SSCM includes evaluation of the environmental impact, a multi-disciplinary perspective of the entire product life-cycle, and considerations for all stages across the entire value chain for each product [11].

SCM research rarely investigates the social aspects of sustainable development, such as labor practices, gender equity, wealth distribution and fair wage [26].There are a wide range of issues in sustainability development including public policies, political systems, corporate citizenship, international trade, social equity/justice, and economic growth / development. With respect to supply chain strength and environmental performance, one expects that as supply chain strength increases, manufacturing performance (measured through

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costs, quality, delivery and flexibility) are expected to improve. For example, green partnerships are positively associated with quality, delivery and flexibility performance as well as improving environmental performance [26]. Strong competition among suppliers and more demanding customers promotes fair wages and human rights within the corporation and motivates companies to contribute more to the well-being of society through local community involvement.

Firms are increasingly required to offer high quality, innovative products at competitive prices, and to develop supply chains that are sustainable in the long run [11]. NPD is the overall process through which an idea is transformed into a commercial product [27] and includes the idea generation, market research, product design, and detail engineering phases. In order to remain competitive in today's marketplace, SCM must address sustainability issues in NPD. Sustainable product development is the process of developing an improved sustainable product or service for the market [28]. Sustainability integration into NPD is still evolving and is increasing the product design complexity [12]. External factors that encourage sustainable NPD include competitors, governmental agencies, regulatory bodies, while internal factors include top management vision and strategy, and employees [29]. Product designers can significantly influence the product's sustainability over its entire life. Sustainable products addresses fulfilling the users' needs with the purpose of reducing environmental and social impacts of products while providing economic value to the company during the whole product's life cycle [30]. Green NPD, which focuses on the environment and economic sustainability aspects, is fundamentally the same as traditional NPD; however, green NPD increases the complexity [31]. A 2009 Forrester study indicated that 84% of companies surveyed had green or socially responsible products in NPD or on the market [32]. However, as recently as 2010, there was little knowledge on why and how companies integrate environmental sustainability into NPD [33].

Therefore, there is a need in today's society to address how to integrate sustainability – all three dimensions of ecological, environmental and social – into NPD and SCM. We continue by reviewing key managerial recommendations to address this. Then, since managers use metrics and frameworks to evaluate the system, we review some sustainability metrics and frameworks. We conclude with a summarization of our recommendations.

2. Managerial recommendations

Current literature reviews provide limited overviews of difficulties and challenges – such as cost implications, inadequate knowledge and skills, ambiguous laws and regulations, and communication and coordination complexity-in managing sustainability in NPD [31, 34]. While current efforts appear to focus on industry and policy levels, the managerial level lacks direction and attention to integrate sustainability into NPD practices. Previous research in New Product Development (NPD) within Supply Chain Management (SCM) over the past 15 years revealed critical managerial recommendations: top management support and development of an integrated NPD-SCM strategy, resource allocation, financial support, and support for a

common, shared information system; a focus on marketing demands; supplier/customer integration; integrated networks; a coordinated, cross-functional team; and a clear product vision [35-37]. Based upon experience and a literature review of the cases, empirical reviews, and other available literature, these recommendations are still relevant to NPD in SSCM. As summarized in Table 1, we continue with a discussion of each of these recommendations to incorporate sustainability into NPD in SCM.

Best Practices
Recommendation: Top Management Support: Development of an Integrated Sustainable NPD-SSCM Strategy, Resource Allocation, Financial Support and Common, Shared Information System • Set the sustainable vision, mission, scope, goals and explicit strategic targets that effectively direct NPD decisions towards sustainable products. • Develop a cohesive sustainable NPD strategy as well as a green company policy. • Align the organization and its associated supply chains toward delivering sustainable products and services. • Support through resource allocation, financial support and a common, shared information system. • Develop specific managerial skills and coordinate processes for all three aspects of sustainability. • Adopt proactive supply chain practices. • Align sustainable NPD through processes and products. • Provide process management support through buyer-supplier integration and such activities as creating a management-level sustainability position and employee sustainability training. • Encourage social sustainable development through increasing designer social knowledge, improving transparency and encouraging fair trade practices. • Support the development of a common, shared database for integration. • Negotiate NPD-SSCM application and align with products and processes. • Develop a green company policy. • Create a management sustainability position. • Increase management knowledge through entrepreneurial and innovation skills.
Recommendation: Focus on marketing demands. • Develop market planning initiatives with a focus on end customer requirements. • Incorporate sustainability into NPD by evaluating product safety for the end-user. • Detect marketing needs for ecological and social demands and restrictions. • Evaluate market changes to comply with company goals, resources and capabilities. • Analyze the market for sustainable needs and capabilities. • Develop procedures and rules to encourage green NPD development. • Evaluate consumer's care for the environment and community – and how much they are willing to pay to support these concerns – and develop appropriate sustainability strategies. • Manage environmental impact through goal-oriented and market-based mechanisms that provide flexibility. • Consider market orientation, green targeting, green positioning, and customer outcomes influence green NPD. • Use structured management processes to bridge market and process management.
Recommendation: Supplier/Customer Integration • Select partners with the same guiding sustainability principles. • Co-evolving, collaboration and joint development of products and processes that discourage pollution. Prevention and innovative environmental technologies, joint knowledge development and development of a code of conduct.

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Best Practices
• Use environmental requirements in the process of selecting new suppliers as well as the continual evaluation of existing suppliers. • Develop closer relationship with suppliers by holding regular meetings for enhanced communication, activities that focus on communication and trust-building toward better relationships, and a focus on improving joint decision-making. • Encourage a moderate level of cross-functional integration, and either a low or high level of customer integration into NPD efforts. • Encourage collaboration and communication between supply chain members through procedures that encourage a proactive sustainability approach. • Identify risks associated with environmental and social problems prior to public exposure. • Analyze the entire product lifecycle. • Develop partners through assistance and teach new methods, training, providing expert knowledge, and financial support. • Information and data flow between supply chain members encourages collaboration and NPD efforts are more effective. • Institute activities that ensure that suppliers use environmentally sensitive procedures. • Pay attention to monetary and non-monetary costs of implementing integration practices in NPD that may outweigh the benefits. A moderate level of cross-functional integration but either a low or extensive level of customer integration (not moderate) in NPD is recommended. • Encourage social sustainability in the form of decent working conditions by supplier employees by providing training and expert knowledge.
Recommendation: Integrated Networks (Practices/Processes & Information Technology Management) • Streamline formal processes and coordination between the stakeholders. • Use product data management, process improvement management and engineering project management to address the globally-dispersed processes that extend across departments, companies and international borders. • Incorporate Product Lifecycle Management (PLM) best practices into sustainable NPD, including formalization of processes (such as product-focused sustainable data handling processes, process flexibility improvement; common change management processes for economic and environmental success, and workflow management for economic process execution) and cross-functional work (including cross-company and cross-functional sustainable process alignment). • Support Enterprise Resource Planning system data interchange between supply chain members. • Use a product/process approach to avoid un-necessary steps that do not support sustainability efforts. • Use a central location for data management and storage to reduce data duplication and data inconsistences. • To mitigate the increased risks associated with SSCM, companies should utilize individual company monitoring, use generalized standards and certifications (such as ISO-14001). • Establish a central location for data management and storage, and use a common development platform. • Security concerns across informational boundaries increase with SCM; however, through trust –building procedures, collaboration between supply chain members improves.
Recommendation: Coordinated, Cross-functional Team • Require and support departmental cross-functional collaboration. • Must be supported by top management. • Define development team roles clearly.

Best Practices
• Include globally-inclined sustainability experts.
• Collaboration improves through sharing information which focuses the organization on common goals, sharing resources, communication, creating knowledge, using common procedures, trusting and jointly making decisions.
• Remove barriers that inhibit collaboration such as functional silos and silo thinking solely focused on economic development.
• Adopt a product/process approach.
• Encourage a resource-based view that reviews inter-firm resources towards increasing competitiveness.
• Encourage cross-functional and cross-company environmental and social data provisioning.
• Manage key sustainability resources.
• Define and jointly control data management resources.
Recommendation: Clear Product Vision
• Develop a clear definition of products.
• Integrate a seamless product delivery process for new product introduction.
• Match market requirements and value stream objectives.
• Develop a clear, defined, sustainability scope and targets that are operationalized.
• Meet a minimum threshold of acceptable performance.
• Use customized tools, databases, design for sustainability methods, and supply chain tools.
• Respect sustainability issues in process definitions.
• Define roles and responsibilities clearly.
• Educate and encourage NPD designers in sustainability.
• Build active knowledge networks.
• Management needs to establish specific sustainability targets.
• Balance program and project management toward a standardized sustainable product development process.
• Address aesthetic design advantages, which is especially important for sustainable products.
• Encourage use of Design for the Environment, design-oriented work for green operations and green supply chain management.
• Understand the entire lifecycle, the impact upon the environment at each of its stages, and incorporate product attributes and manufacturing processes into design.
• Address remanufacturing design concerns, such as product/component durability, level of re-manufacturability of products, managing the highly unpredictable return stream, consumer preferences between new and re-manufactured products, and supply constraints.
• Consider appropriate alignment of re-manufactured products to its associated reverse supply chain.
• Address Extended Producer Responsibility issues associated with new product and its associated processes.

Table 1. Summary of Key Recommendations and Best Practices in NPD-SSCM

2.1. Recommendation: Top management support: Development of an integrated sustainable NPD-SSCM strategy, resource allocation, financial support and support a common, shared information system

Without question, one of the most critical aspects of developing NPD with SSCM is Top Management support. Top Management involvement in sustainable NPD, which are the processes that the company's senior staff use to promote NPD activities [12, 29, 38-40], is

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essential and includes strategy development, resource allocation, financial support and support for a common, shared information system. Top management needs to actively promote sustainability through its vision, mission statement, scope, and goals towards directing NPD decision towards sustainable products [34]. Research supports the best practice in sustainable NPD as developing a sustainability vision and explicit strategic targets [41, 42]. (Unfortunately, in many industries and firms, sustainability pressures and incentives may be absent or fuzzy [34], and companies struggle with developing a sustainable vision [18]). Recent research demonstrates that many companies have some level of sustainability in its strategy and vision [18]. In today's business environment, sustainable NPD is internally-driven as external pressures and incentives are lacking in many industries [18]. A cohesive strategy, and not merely utilizing one sustainability method, tool or metric (such as life-cycle assessment or design for environment), is required to drive sustainable NPD [34]. Due to the wider array of factors, it becomes more difficult to define a strategy, vision and targets. Factors to consider include: environmental benchmarking, policy, and coordination; cross-functional coordination; top management support; and supplier involvement [41, 42]. As management begins to address sustainability, they should focus on what sustainability means for their business and products through defining a sustainability strategy, scope, targets, and processes first, and worry less about the metrics at the beginning [18].

Top management must strategically align the organization and its associated supply chains toward delivering sustainable products and services. Effective sustainable NPD requires coordination efforts with other supply chain members [18]. To be successful, companies should follow a sustainability strategy guided by the triple bottom line and place equal importance on all 3 dimensions of sustainability in decision-making [14]. For example, companies should adopt pro-active supply chain practices, such as learning from partners and other sources to gain knowledge regarding sustainability. In general the ability of companies to be innovative is especially important for SSCM [43].

With respect to environmental sustainability, top management must align green initiatives with the strategic objectives of the firm [11], which may be done through developing a 'green company policy' with a focus on green product innovation [31]. The green company policy indicates the managerial commitment to sustainable NPD through its values, norms and management practices that limit the firm's environmental impact [31]. The existence of a green company policy has a major influence on green product innovation [33]. Green demand and green regulations do not affect green NPD in the same manner in all firms [44] as industry effects on green NPD implementation are strong and significant [45]. Complex interactions between industry environment and firm specific factors exist [31]. Corporate reputation, specifically green leadership, may compensate for low financial and customer performance of green products, and is an outcome of green strategies [31]. A stronger feeling of identification with the organization due to green NPD may also result. A reputation of green leadership is directly related to a reputation of technology leadership as very green product innovations generally require advanced technology development [46]. Traditional NPD literature implies that different performance outcomes should be used for radical products than incremental

products, and similarly, a different set of performance outcomes should be used for green and non-green products [31].

With respect to social sustainability, companies are starting to recognize the need to create social values along with profit generation and environmental protection, and the concept of corporate social responsibility is growing [26]. Social sustainability issues are difficult to incorporate into sustainable NPD, but through the corporate mission, vision, policies and strategies that top management utilizes, upper management may positively encourage designers to consider social sustainability issues in their decision-making. Additionally, training designers in social sustainability increases their understanding of the complex issues and encourages developing socially sustainable designs and processes. Training documents that promote sustainable NPD include: corporate mission, corporate performance, corporate responsibility, sustainable product attributes (e.g. healthy), sustainable packaging, reduced waste, energy reduction and reduction of carbon emissions [18]. Training employees in sustainability may provide a competitive advantage over other suppliers [18]. As an example, in 2009, Walmart's pledge to broaden its sustainability efforts to all functions within the company, to all parts of the world where it does business, and to work with suppliers (e.g. Unilever and Proctor & Gamble) and with NGO's (e.g. the China Green Foundation) [47]. Best supply chain practices require more transparency in the supply chain due to social implications of an organization within and outside of the organization [26]. As supply chain strength increases, the supply chain may positively impact upon fair trade throughout the world.

In general, the NPD process with sustainability is generally the same as traditional NPD; however, the underlying features and mechanisms needed to address the increased complexity require specific managerial skills and coordination [31]. Management skills to develop sustainability involve innovation and entrepreneurial skills that encourage supporting sustainability knowledge [18]. Management needs to accept a certain amount of uncertainty in sustainability NPD, and encourage proactive capabilities through exploration, experimentation, double-loop learning, creativity and entrepreneurship [18].

Top management needs to insist on product and process alignment through instilling the product vision across departments. Top management establishes processes and the power to change processes resides with them. Top management provides a strategic view of the product life cycle and oversees change management [12]. Top management is involved in process management through establishing processes with development partners that encourage design team competence and remove process issues [12]. Top Management needs to articulate that sustainability is critical to the company's future and important in all buyer-supplier relationships (and a 'shared focus') as well as proliferating resources to support sustainability efforts through such efforts as creating a management-level sustainability position and employee sustainability training [18]. For example, top management's statements in training documents demonstrate upper management's support for 'protecting the earth's resources as the right thing to do'. Top management is also responsible to develop process that assist in coordinating resources toward a sustainable product design [18].

Top management needs to provide the financial resources in various business areas to encourage employees' knowledge in sustainability to grow, to utilize environmentally

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processes within the organization and supply chain, to develop stronger relationships with their suppliers and customers, and to develop and maintain an integrated, common, shared database. Similarly, top management needs to provide resources and funds to establish a common, shared database [12]. A centralized, thorough, operating product data management system, while expensive, can reduce development costs, shorten time-to-market, improve consistency and data flexibility [12]. Successful data management systems require time, expertise and resources, and a good development application. (It important that top management negotiates the application's capabilities and aligns it with the processes and products).

As an example of this critical recommendation, over the past 20 years, IBM, through its business operations and its products and services, demonstrates the relationship between economic performance and environmental/sustainability leadership [48]. IBM embedded sustainability concepts in its NPD processes and its internal continuous improvement processes. IBM's best practices in sustainable process development include: development, maintenance and integration of business and sustainability strategy; seamless execution and maintenance of operations and sustainability initiatives; develop, promote and maintain a culture of sustainability performance; and build an organization and management system to drive and execute integrated operational and sustainability goals [48].

2.2. Recommendation: Focus on marketing demands

In today's customer-oriented environment, another recommendation follows. A NPD-SSCM strategy needs to seamlessly incorporate critical market information into these processes and focus on the end customer. Consumers are increasingly aware of environmental and social responsibility issues and their purchasing decisions are taking these into account [32]. For example, some companies seek sustainability certifications, such as ISO-14000 (for environmental standards) and ISO-26000 (for social responsibility standards), as ways to demonstrate their engagement in sustainability [29]. Companies that lack certification or fewer then their competitors may trigger a loss of trust of negative images to the customer [29]. In response, consumer product strategists are working to bring environmental and socially responsive products to market through focusing on the key stages of the product life cycle [32]. Through product lifecycle management, managers expect operational benefits, such as cost reduction and risk management reduction, and they may influence consumer's experiences, which potentially increases revenues and market share [32]. Gradually, management is recognizing that environmental impacts of products over their life-cycle can best be managed through goal-oriented and market-based mechanisms that provide flexibility [11]. While consumer's interested in supporting environmental and social issues grows, it is important that consumer product strategists evaluate the consumer's care for the environment and community – and how much they are willing to pay to support these concerns – as they develop appropriate sustainability strategies [32]. Until product sustainability is treated as unequivocally positive for the end consumer, companies will struggle with sustainability efforts and marketing products that are more sustainable [49]. Therefore, marketing efforts need to understand the end customer and develop strategies to positively influence them.

As mentioned previously, managers can stimulate green NPD through a green company policy, and through these actions, managers can extend the product's market orientation [31]. Specifically, to build an extended market orientation toward green NPD that can balance green and non-green issues during the NPD process, managers should implement procedures and rules that encourage green NPD [31]. Designers need to balance the consumer's perceived trade-offs between product performance and sustainability [49]. To minimize misunderstandings, a structured management process with market planning and process management is required [12].

Market planning evaluates current market needs and compares them with company capabilities to meet these needs [38-40]. Detection and pursuing an understanding of end customer requirements is necessary to fulfill those requirements [12]. In order to accomplish this, current best NPD into SSCM success factors (which are supported by Product Lifecycle Management (PLM)) includes incorporating sustainability into NPD by evaluating product safety for the end-user, detecting marketing needs for ecological and social demands and restrictions, evaluating market changes to comply with company goals, resources and capabilities, and analyzing the market for sustainable needs and capabilities [12]. Customer feed-back for future products can be incorporated through web-based applications and an integrated database [50]. Changes in market requirements build a source for the next product concepts and need to be evaluated with respect to sustainable new product development, capability for introduction and resource skills [12].

Market orientation, green targeting, green positioning, and customer outcomes influence green NPD [31]. An important driver of successful product innovation strategies is the proposed market orientation (the processing of information about customers and competitors), and taking this a step further, research on sustainable NPD indicates that processing information about non-market stakeholders (regulators and special interest groups) is a critical antecedent of green product introduction [31]. Additionally, the newness of the innovation is another product characteristic that is associated with green NPD as well as market orientation and performance. With respect to the introduction of green NPD into the market, strategies are characterized by the degree to which green aspects are incorporated into green targeting (degree to which a consumer segment values green attributes) and green positioning (degree to which green attributes are used to communicate to the market how the product differs from existing products). Green targeting extends from niche to mass marketing; while green positioning firms may position green attributes at the core or not at all [31]. Greenness and industry type affect green targeting, that is, green products tend to be targeted at a green niche if a green niche is present or emerging [31]. Companies struggle to reconcile greenness with costs [31]. Unfortunately, while green niches are emerging in some markets, market demand for green products in many industries is still low [31]. A positive relationship between green products and reputation may exist as external and internal stakeholders perceptions may be impacted even though the financial outcome may be low. Very green products are often related to very innovative products.

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Managers must understand the importance of marketing of green new products which is very complex due to factors such as greenness of the product and industry factors, which impact upon green targeting and green positioning.

2.3. Recommendation: Supplier/customer integration

As [51] advocates there is a definitive link between product characteristics and supply chain structure, as channel structure plays an important role in product success [52]. Selecting the right supplier and forming the right type of relationships is important in building an effective supply network [51]. Improper channel design can increase costs and create adversarial supply chain relationships [8] as innovative products are best delivered through responsive supply chains while functional products are better served through efficient supply chains.

A critical challenge to sustainable supply chains is to select suppliers that follow the same guiding principles with respect to sustainability as the company, and to extend this up the supply chain to not only the direct suppliers but the entire supply chain [15]. Critical sustainability NPD questions to address include [15]:

- Which components should be made or bought?
- Which suppliers should be used for those products that are to be purchased?
- How should product design related issues be coordinated?
- What information technology infrastructure is needed to support supply chain operations?
- What enterprise production and inventory decisions best support optimal operation of the supply chain?
- What transportation strategies should be used to support the supply chain?
- What is the best way to coordinate demand planning and forecasting among all suppliers?

Sustainable supply chains are designed differently from conventional supply chains as an important change lies in searching and selecting the right partners for the supply chain [14]. Selection takes place over time and may include co-evolving, collaboration, and joint product and process development. Co-evolving evolves by improved relationships amongst members. An example is a pork producer forming a partnership with an environmental engineering bureau with similar view on farming [53]. With respect to co-evolving, joint growth in knowledge and partner development on environmental and social issues may assist toward a sustainable supply chain. Jointly implementing a code of conduct would improve the social aspect of SSCM. Collaboration with suppliers and customers is linked to the adoption of pollution prevention and innovative environmental technologies [26]. Sustainable products require internal and external interaction and collaboration in NPD [54]. Collaboration and joint development includes NPD [12, 29-57] and process development [58]. Contract-based alliances raise organizational challenges for trust and data management sharing, interoperability and communication [12]. Joint product and process development includes holding regular meetings for enhanced communication, activities that focus on communication and trust-building toward better relationships, and a focus on improving joint decision-making [14].

Process alignment and management is easier in collaborative arrangements like Joint Ventures [59]. The more partners trust each other, the higher the quality and intensiveness of information exchange [12].

Buyer-supplier relationships continue to be critical to incorporating sustainability in NPD [18]. Suppliers should be selected based on their technical superiority and cooperativeness so that a close relationship with critical suppliers can be formed [52]. Successful implementation of new and more sustainable product designs depend upon suppliers' willingness to cooperate in sustainability improvements and to implement changes; however, many suppliers have little to no interest in sustainability [18] particularly the further partners are from the end customer. Joint sustainability initiatives emphasize supplier/buyer relationships in NPD/SSCM lead by top management and linked to metrics [18]. Shared values, goals and understanding are important to the formation of a successful supply chain relationship [18]. An often cited best practice in SSCM is the development of closer relationship with suppliers; however, building close relationships can be difficult [60]. Trust and reliability make the relationship between the partners less exposed to opportunism risks and successful NPD includes process alignment with development partners [12]. Practitioners should pay attention to monetary and non-monetary costs of implementing integration practices in NPD that may outweigh the benefits [61]. Specifically, a moderate level of cross-functional integration, and either a low or extensive level of customer integration (not moderate) in NPD is recommended.

The purchasing manager's role and abilities to recognize environmental issues connected to suppliers is also important in NPD. The coordination between environmental, Research & Development (R&D) and purchasing departments has a significant influence on product improvement activities, particularly with respect to the environmental supply chain, and is an important feature of environmental supply chain cooperation [62]. Cooperation with suppliers brings positive effects on supply chain management initiatives as the closer relations to suppliers concerning product-related activities are connected to higher tendencies for cooperation on environmental issues [63].

The supply chain network structure concerns the way supply chain members interact with one another including their long-term relationships, and selection and development of partners [14]. Development of partners may include assistance and teaching of new methods and financial support even in developed countries. Selection may be by abilities [64] and willingness to engage in sustainable practices [53]. Issues surrounding political strength in supplier/customer relationships still exist. Research is still needed to address which company oversees and decides upon final processes, suitability of similar and different sustainability practices between supplier and customers, and differences in sustainability visions between corporations [12].

Information and product data flow across companies is important to successfully establish a joint product development with suppliers toward sustainable products [65]. Extensive data collaboration with suppliers provides a chance to increase supply chain wide master data, which facilitates cross-functional work [12].

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Environmental innovation and supplier involvement in the buying organization's processes is related to improved environmental performance [26]. Environmental performance as measured by waste recycling, greenhouse gas reduction and environmental innovation is positively related to supply chain strength. As demonstrated by Nestle, improved buyer-supplier relationships may lead to better environmental performance [66]. As supply chain strength increases, the network becomes richer, proactive environmental management becomes a competitive advantage and a differentiation factor [26]. Therefore, the adoption of standards (such as ISO14000) and corporate environmental behavior are positively affected by the quality and quantity of supply chain relationships [26]. Building close bonds to a supplier and investing in the supplier's environmental awareness is the most important prerequisite for subsequent environmental work [60].

In any supply chain, supplier-buyer metrics need to be jointly delineated, monitored and managed. Reflective control compares and evaluates the functionality to the needs of the supply chain, through financial metrics, key performance indicators, transparency, and information sharing. An example of reflective control is Qualitative Partner Control and Auditing, whereby certification by a third party, auditing and analysis occur through written scorecards used to evaluate suppliers. An environmental audit of a supplier is a good method to monitor supplier compliance with the requirements; however, audits are not commonly performed [60]. Similarly, corporations need to institute activities that ensure that their suppliers use environmentally sensitive procedures, such as ISO-14000, or participate in an industry's voluntary code of conduct [26]. ISO-14000 represents proof of environmental performance, the supplier's environmental ambitions, advancement of supply chain practices of the customer, and the ambitions of certification bodies [60]. The value of ISO-14000 is a combination of the supplier's own environmental ambitions, advancement of environmental supply chain practices of the customer company and the ambitions of the certification bodies [60]. IKEA, Sony, Ericsson and Volvo established detailed environmental and sustainability qualification schemes for their suppliers [60]. In general, another best practice is to use environmental requirements to select new suppliers and continuously evaluate existing suppliers for sustainable practices. However, when reviewing suppliers located in different countries, the decision-maker should consider the level of environmental legislation enforcement. If the enforcement is weak, a requirement from a customer to demonstrate legislative compliance may carry different meanings, and therefore, requires different attention as compared to countries with advanced legal control and sanction systems [60].

Green purchasing is considered to have the most significant impact upon sustainability as roughly 60% of the cost of a product can be attributed to purchased materials [67]. Research in green NPD dominates (e.g. [68]) as suppliers play a significant role in green innovations [69]. Within green purchasing research, specific issues addressed include cooperation and communication between supply chain members to achieve a proactive sustainability approach, risk management to identify environmental and social problems prior to public exposure, and analysis of the total life cycle of the product [70].

Life cycle analysis (LCA) addresses the environmental impact of every supply chain stage (from raw material extraction, through material processing, manufacture, distribution, use,

repair, maintenance, to disposal or recycling), and in particular, focuses on supply chain partnerships. LCA is a comprehensive approach to evaluate environmental impacts of products [71] and it is one of the most commonly discussed pro-active methods used [14]. LCA emphasizes the physical substance flow and chemical changes, such as ozone depletion, smog formation and acidification as it focuses on human health, ecosystem quality and resource use [15]. Chemical and toxic substances negatively influence a company's LCA [72], and therefore, reducing chemical and toxic substance use is of interest to company's pursuing sustainable products [73]. Current research indicates a gap and need for a more holistic, relational research in this area [10]. ISO-14000 provides principles, frameworks, requirements and guidelines for LCA [74-75]. LCA seeks to minimize the negative effects on the environment by looking at all phases of a product's life-cycle and taking action where it is most effective [29]. LCA requires expertise, and assumes detailed information on products, parts, use and production is available for all product life cycle phases [18]. Therefore, LCA's effectiveness is limited in early product design [76] and provides limited guidance to immature NPD organizations due to methodological problems, lack of knowledge and data [18]. Other problems with using LCA include weighting the various impacts against each other and the limited suitability for radical new products [31].

Evaluating supply chain partner's social sustainability can be difficult as many proposed indicators are dependent upon the economic resources available to a family (poverty, nutritional status, healthcare, life expectancy and living conditions). In the US, corporations may be evaluated on the average wages versus the cost of living in the region, wage equity, gender and minority wage equity, healthcare benefits, philanthropic activities, educational initiatives and workforce job safety [15]. Potential indicators for social sustainability include: labor equity (distribution of employee compensation within an organization measured through average hourly labor costs to the total compensation package for the highest paid employee), healthcare (corporations role in providing and supporting healthcare of its employees and their families measured through healthcare expenses per employee versus market capitalization per employee), safety (of the workplace for its workers possibly measured as the ratio of average days not injured to the total days worked), and philanthropy (corporations play important financial roles within a community potentially measured through the ratio of charitable contributions to market capitalization) [15]. Another possibility is to consider the United Nations Division for Sustainable Development (UNDSD) measures, which promotes meeting basic needs through poverty reductions, human health improvements and ecosystem protection as well as higher level needs such as education and gender equity. The UNDSD framework classified indicators first by primary dimensions (social, environmental and economic), then by theme (e.g., education benefits, health benefits) and then by subtheme (literacy) [77]. For social sustainability, the categories include equity, health, education, housing, security and population [77]; however, many indicators may be difficult to incorporate into decision-making [15]. Another method to ensure decent working conditions for the supplier employees is to providing training and expert knowledge [60]. Doing so encourages environmental awareness and prepares the supplier for more advanced work.

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2.4. Recommendation: Integrated networks (practices/processes & information technology management)

In NPD, streamlined processes and coordination between the stakeholders are required [12]. Best practices to develop this includes using product data management, process improvement management and engineering project management to address the globally-dispersed processes that extend across departments, companies and international borders [12]. Formalized processes between supply chain members support doing the NPD project right and clearly-defined routines assist in developing a dedicated output being agreed upon by all development partners [38-40]. Collaboration links structural aspects of the supply chain to business processes including decisions on how to technically and logistically integrate supply chain partners, addresses the quality of information exchange and the operational processes of the SSCM system [14]. To mitigate the increased risks associated with SSCM, companies utilize individual company monitoring, use generalized standards and certifications (such as ISO-14001). In evaluating sustainability efforts, using a product/process approach avoids unnecessary steps that are not environmentally, socially and economically sustainable [12]. Structured process management to guide projects, align targets and manage sustainability targets as demonstrated by companies further along the sustainability maturity [18]. From a NPD and supply chain standpoint, as product complexity increases with a large number of target components, the value of short lead times increase and the environmental impact due to shorter distances decreases [78].

Product Lifecycle Management (PLM) addresses the information integration through all phases – including NPD – to every supply chain member [79]. PLM enhances cross-functional collaboration, reduces product data inconsistencies, and improves coordination and control of product engineers to improve NPD [80]. Information on revenues, costs, time, energy and material information is exchanged across the organization and companies by integrating product-specific processes, skilled people, and product data [29]. PLM's purpose is to streamline product development and assist in innovation. The PLM information system must support data exchange from first conceptualization through its disposal, should allow for any data component to be directly accessible, store relevant information, serve all functional areas, potentially offer reuse of the product information and provide fine-grained information regarding the product's description and rationale [79]. The PLM must support design and manufacturing process components for large volumes of product information both horizontally and vertically to systems such as ERP systems [79]. PLM supports collaboration through a central data provision for product data management [81]. In PLM, processes need to be designed according to the product and material flow in order to facilitate and accelerate product development [12]. Sustainable NPD success factors supported by PLM include formalization of processes (including product-focused sustainable data handling processes, process flexibility improvement; common change management processes for economic and environmental success, and workflow management for economic process execution) and cross-functional work (including cross-company and cross-functional sustainable process alignment) [12]. PLM supports operations management in reducing managerial complexity in NPD [82]. A common product development platform toward economic product development

balanced with program and project management toward a standardized sustainable product development process is also recommended for a successful NPD [12].

With respect to sustainability, acquiring data on environmental performance and social sourcing is enabled by product data management [12]. An environmental management system (such as ISO-14000) requires organizational structures, routines, and a knowledge base to manage the company's direct environmental aspects [60]. Organizational benefits are connected to legal compliance, while financial benefits originate due to a reduction in resource use, waste reduction and operational efficiency improvements [60]. External driving forces for an environmental management system come from potential corporate image improvement, market advantages, satisfying customer requirements and public pressures, while internal driving forces for working with supply chain related environmental issues include the link between the purchasing function and other functions, purchasing procedures, partnerships with suppliers, technical skills and environmental knowledge that impact upon the adoption of supply chain activities [60]. Product data management supports the idea of a single source for product data and product sharing, which enhances collaboration activities [12]. Data management plays a significant role in PLM to store relevant product data, especially the data that is integrated with development partners [29]. In PLM, a central location for data management and storage is required to reduce data duplication and data inconsistencies [12]. Research implies that investment in environmental management systems is related to the location in the supply chain versus the end consumer [60]. The closer partners are to the end consumer, awareness increases; while the farther partners are less aware. Additionally, security concerns across informational boundaries increase with SCM; however, through trust –building procedures, collaboration between supply chain members improves. Collaborative product development speed increases after the first years when uncertainty in data security is replaced with mutual trust [12].

2.5. Recommendation: Coordinated, cross-functional team

Cross-functional collaboration among departments is a success factor for sustainability in NPD [83]. In today's business environment, cross-functional development may include internal organizational integration as well as inter-firm (external) collaboration [61]. Top management must support cross–functional work – where people from different areas work jointly toward a new product [38-40].

Cross-functional teams reflect the core values of sustainable new product development [84]. The development team needs to know their roles and functions in detail, so collaboration can occur [85] and include experts with sustainability capabilities [12] Global design activities require global-acting experts who are responsible for several projects which provides the advantage in standardization and expert-resource utilization [12]. Knowledge management activities support team training and learning for NPD personnel and may facilitate knowledge creation and sharing [18].

Engineering collaboration across companies is essential to develop innovative and sustainable products. Collaboration is critical for product improvement, cycle time and cost reduction [86]. Other benefits to cross-functional integration in NPD include linking

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functional viewpoints, information exchange beyond functional boundaries [87]; efficient resource allocation and pooling of capabilities, providing access to new skills or technologies, and sharing of R&D costs and risks leading to enhanced NPD [88-89]. Successful collaboration is dependent on technology and organized processes [86]. The first step towards collaboration is for a company to remove functional silos and adopt a product/process approach [90]. Specific to sustainability, a resource-based view that reviews the inter-firm resources that are valuable for increased competitiveness is needed [12]. Factors that assist in collaboration include: sharing information which focuses the organization on common goals, sharing resources, communication, creating knowledge, using common procedures, trusting and jointly make decisions [26, 29, 86, 91].

A collaborative environment, tools, interoperability standards, and architectures must be coordinated so that barriers do not prevent collaboration. Barriers to collaborations include poor communication and a lack of process harmonization [92] that induce silo thinking [12]. Global teams in NPD require suitable applications supporting communication and collaboration to enable teams to work at different locations [63]. Barriers include: organizational costs, time and efforts for team meetings, coordinating the workflow of team members from various functional units, solving inter-functional conflicts and the potential information overload of NPD members' processing capabilities [93], opportunistic behavior by one, knowledge spillover, distrust, costs of monitoring inter-firm partners, and communication problems due to different organizational cultures [89, 94].

NPD Success Factors supported by PLM includes: cross-functional and cross-company environmental and social data provisioning, avoidance of silo thinking solely focused on economic development, and management of sustainability key resources [12]. In strong collaborative relationships, data management is defined and controlled jointly [12].

3DCE (three-dimensional concurrent engineering) is a concept coined by [51], which is a potential NPD model supported by concurrent engineering [52]. NPD literature focuses on support for concurrent engineering, early supplier involvement, understanding customer requirements and channel structure. While 3DCE extends this view as it focuses on the product, processes and supply chain simultaneous design through multi-functional teams early in the process that may include suppliers and customers. Implementing a new system and effectively managing processes requires active participation and engagement of top management to build a shared vision. These concepts, such as 3DCE and concurrent engineering, need to be extended to include sustainability concepts in NPD.

2.6. Recommendation: Clear product vision

During NPD, designers need to evaluate supply chain processes and decisions (such as logistic channels, the optimal location choice, mode and frequency of transport, inventory levels, and degree of postponement appropriate for the particular product and its life cycle stage) as well as predict and understand product life cycle aspects associated with duration, delivery window, volume, variety and variability [9]. The product delivery process and a new product introduction must be as seamless as possible so products flow as required by the customer

throughout the life cycle. The product and its associated supply chain must match market requirements and value stream objectives in order to best compete [8]. During the introduction stage, the key order winner is the lead time from concept through design availability and capability, which favors a 'design-and-build' strategy [9]. During growth, product availability during the increased demand time period is the order winner and as a result the product moves towards an MRP push-based supply chain [9]. At maturity, the Kanban supply chain becomes the most effective form as cost is the critical order winner [9]. Finally, at decline, as demand decreases, the MRP supply chain becomes relevant, until demand significantly tails off and the 'design-and-build' facility is relevant [9].

Unfortunately, there is a wide gap between consumer's articulated support of sustainability and disproportionately low levels of actual 'sustainable consumption' [95]. To management this implies that only some consumers may be willing to sacrifice some degree of functional performance for sustainability; products must still meet a minimum threshold of acceptable performance, and it is critical to reassure consumers that the product meets an acceptable minimum level of functional performance [49]. Therefore to promote sustainable products to market segments, it is important to find ways to improve consumer's confidence toward these products. As sustainability importance increases, consumers are increasingly likely, due to an increase in guilt, to choose the sustainable-advantaged product. In a case study, companies with a lack of customer demand for sustainable products found that customers tend to stick to conventional products instead of buying eco-products, even if price, quality and functionality are the same [18]. Researchers continue to explore the perceived trade-off between product performance and sustainability [49].

Since consumers often believe there is a trade-off between sustainability and functionality [96], they tend to choose the product with superior functional performance over the sustainability-superior product until a minimum threshold of functional performance is achieved [49]. The trade-off depends upon the degree to which consumers' value sustainability and is mediated by consumers' feelings of confidence and guilt. Superior aesthetic design has a disproportionately positive effect on the likelihood of sustainability-advantaged (versus performance-advantaged) products due to the effect that superior aesthetic design has on overcoming the potential lack of confidence in sustainable products [49]. Therefore, a key recommendation for company's interested in marketing sustainable products is to develop market-leading product aesthetic design capabilities [49].

Recently, research on green product innovation activities is growing and includes investigating strategy development, market and environmental performance of green product innovations, and design strategies-such as recycling and remanufacturing [31]. Green NPD is related to market orientation and green company policy as antecedents of product characteristics must be balanced (greenness, relative advantage, costs and newness) and introduction characteristics (green targeting and green positioning) must be established [31]. In turn, these product characteristics determine NPD financial, customer, technological and reputation outcomes. Other aspects of green NPD include evaluating environmental concerns, design specifications, project team coordination, upper management support, and

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product outcomes. While reputation may not be a measurable outcome of a green NPD process, managers need to consider both internal and external reputation impact in the NPD process [31]. Methods for addressing specific sustainability issues include: Design for Environment (DfE), design-oriented work for green operations and green supply chain management [23, 56, 70], and other tools and metrics that can be used to make design decisions more sustainable.

In mature sustainable NPD processes and organizations, sustainability scope and targets are clear and operationalized; customized tools, databases, design for sustainability methods, and supply chain tools are used; sustainability issues are respected in process definitions; roles and responsibilities are defined; and NPD designers have expertise in sustainability and are active in knowledge networks [18]. Management needs to establish specific sustainability targets, such as energy efficiency, carbon dioxide footprint, product weight, materials (recyclables and recycling), sustainable packaging, and hazardous substances [18]. Also, a clear definition of products within product development is needed [97].

In NPD, each component's economic, environmental and social impact needs to be evaluated. Product designers need training to understand each of the three sustainability environments. Designers need to monitor NPD and costs through the all of the NPD phases of idea generation, idea screening, concept development and testing, marketing strategy, business analysis, product development, test marketing and commercialization, and to realize that as more information is gathered, it is easier to estimate NPD costs [98].

Case analysis reveals that companies consider greenness to be a product characteristic that must be balanced throughout the entire NPD process against non-green characteristics, such as newness, product costs and relative advantage [31]. The environmental impact of products occurs across the dimensions of materials, energy and pollution [33] and needs to include all supply chain management processes including packaging and transportation activities. NPD designers need to incorporate environmentally conscious manufacturing and product recovery into design, material selection, manufacturing processes, product delivery to the consumers, and end-of-life product management [99]. They need to understand the entire life-cycle and impact upon the environment at each of its stages, and incorporate product attributes and manufacturing processes into their design for the environment.

DfE addresses designing and developing recoverable products, which are durable, repeatedly usable, harmlessly recoverable and environmentally compatible in disposal [100]. Currently, designers are unfamiliar with the associated manufacturing processes, which in turn lead to coordination issues between supply chain members. Research is particularly lacking in the DfE area [10]. In DfE, sustainability attributes including recyclability, energy efficiency, maintainability, and reusability are treated as design objectives rather than constraints [101]. As seen in Table 2, DfE relies on contextual information to select an appropriate DfE strategy [102] and to establish design specifications and requirements [18]. When contextual factors are not well defined, firms may struggle to manage sustainability efforts.

Contextual Factor	Comments
Perceived/expected customer demand for sustainable products	Customers may demand sustainable products or services.
Actual performance of sustainable products on market.	Actual sales feedback regarding sustainable products in the marketplace. Positive sales results reinforce sustainable practices, while negative sales results undermine them.
Competing on Sustainability	Competitors' behavior regarding sustainability may force firms to modify behaviors to stay in the market. Additionally, sustainability may be used as a competitive advantage.
Environmental and Social Laws and Regulations	Firms must comply with laws and regulations.
Sustainability pressure groups/stakeholders	Community and environmental stakeholders may exert pressures to improve a certain aspect of sustainability
Supply Chain Complexities	Customers may 'pull' and suppliers may 'push' sustainable products. Example: suppliers may develop more sustainable methods to mine materials or produce parts, or they may not cooperate with sustainability efforts.

Table 2. Contextual Factors and Comments (Based upon [18])

Reverse value chain activities (reuse, repair, refurbishing, recycling, remanufacturing or redesign of returned products) may create additional competitive advantages [103]. A centralized, efficiency-driven reverse network is not always the most appropriate for re-manufactured goods [104]. When high return rates and recoverable value is high, responsive supply chains focusing on speed through decentralization should be designed. If returned products are unused, consideration to an early product differentiation strategy should be given. Marketing drivers for product re-manufacturability include high production costs for a single-use product, low remanufacturing costs, and low incremental costs to change a single-use product to a remanufactured one [105]. Re-manufacturing valuation, pricing and design decisions include product/component durability, level of re-manufacturability of products, managing the highly unpredictable return stream, consumer preferences between new and re-manufactured products, supply constraints, extent of cannibalization between new and re-manufactured products, competitors in both markets, efforts to gather re-manufactured products, and the reverse supply network [11]. Management and new product designers must also consider the timing and volume of used product returns, re-manufacturability, diffusion rate, and repeat purchase. Additional NPD must consider which components may be reused for manufacturing products, which components will retain their original functionality, and how many times a component may be reused for the same kind of product [11].

Extended Producer Responsibility (EPR) policies are being developed to shift responsibility for life-cycle environmental performance toward producers and away from local municipalities through providing incentives to incorporate environmental considerations into the design

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of products [11]. EPR efforts include product take-back and recovery targets (e.g. home appliance recycling in Japan), disposal fees and material taxes (e.g. states that tax disposal of tires in the US), and design/performance standards (such as fuel efficiency laws in the US). Strategies to encourage EPR that impact upon NPD include changing product design to incorporate end-of-life take back, disassembly and reuse; rationalizing parts and components to decrease material usage, eliminate hazardous substances, and facilitate remanufacturing; and choosing optimal product durability to include planned obsolescence and planned take-backs and replacements. Additionally, EPR considers different contractual arrangements with suppliers and distributors toward joint planning and responsibility over the product life cycle to include reverse supply change structure and remanufacturing. EPR contracts, such as price-replacement interval, two-part tariff and leasing, can assist in supply chain coordination, improve supply chain profitability and lead to environmentally superior product designs [106]. Existing 'fee-upon–sale' types of e-waste regulation cause manufacturers to increase their equilibrium development time and expenditure; however, existing 'fee-upon-sale" types of e-waste regulation fail to motivate manufacturers to design for recyclability. Contrastingly, 'fee-upon-disposal' types of e-waste regulation (such as individual extended producer responsibility) motivate design for recyclability, but often fail to reduce the new product introduction frequency [11].

In recent years, environmental protection programs (such as the Title IV of the Acid rain program developed by the EPA in the US, Regional Greenhouse Gas Initiative in the northeast or the Western Climate Initiative in the western US and the Kyoto Protocol) have been instituted throughout the world to limit and reduce greenhouse gas emissions through 'cap-and-trade' programs. Relative to the discussion here, questions regarding the impact of these programs on sustainable NPD exist. Specific questions that need to be addressed include [11]:

- How do carbon prices affect product line design decisions when different products require different capacities and have different levels of emissions during production?
- How do different regulatory regimes affect a firm's technology choice?

In the future, supply chain members may trade 'emissions' rights within the supply chain to optimize the value chain.

3. Sustainability metrics in NPD/SCM

Many companies are concerned about the measurability of sustainability [18]. Top management needs clear, relevant metrics to track implementation progress, benchmark against other companies and to report their progress to the outside world [20]. The metrics should be linked to business metrics that executives and shareholders care about as sustainability programs built solely upon philanthropy will not survive [20]. For example, to track and monitor customer integration, management may consider using an employee survey or appointing an expert to track benefits customers give to the NPD process and then assess the feasibility of the customers' ideas [61]. To measure the efficiency of internal cross-functional integration,

management should question employees about how the integration practice contributes to the progress of the NPD process, and track the frequency and quality of NPD teams' meetings [61]. With regard to external partners, management may consider monitoring the level of trust and seek allies that offer complementary capabilities [61]. Corporate attainment of sustainability certifications, such as ISO-14000 and ISO-26000, represent a commitment to sustainability.

Several frameworks to evaluate sustainability for the entire product life cycle exist, such as the Dow Jones Sustainability Index, the Corporate Social Responsibility and Sustainability Ratings and Information Database (CSRHub), and Corporate Executive Board [20]. The DJSI monitors sustainability for the entire product life cycle across many functions and is useful at the company level for benchmarking; however, it is expensive and time consuming. CSRHub, which is a broad-based model that is divided into community, employees, environment and governance, gives corporate social responsibility ratings for several companies, industries and countries. With a paid subscription, CSRHub allows additional benchmarking information. Unfortunately, CSRHub is difficult to use to develop a strategy to improve sustainability maturity within R&D and NPD functions. CEB uses several dimensions grouped by focus areas and scores each dimension according to its importance to the organization. With CEB, the organization's effectiveness relative to each dimension and information relative to R&D and NPD is available. Unfortunately, CEB is proprietary and best practice tools and processes for various elements are only available to Council members, which limits its use as an improvement tool.

Specific to NPD and the environment, [107] developed a model that considered the impact of NPD decisions on future resources and environmental conditions. The [107] model uses system analysis to develop the financial performance relative to design and process characteristics that affect future resources and the environment, but does not consider social sustainability. The [107] model focuses on the product definition but is a predictive model rather than an evaluative model. The IRI Sustainability model focuses on R&D and NPD functions that support them, using 14 dimensions organized by strategy and design tool to give a holistic view of R&D and NPD sustainability [20]. Strategic dimensions include: corporate sustainability policy, overall sustainability policy, government policy and regulation, impact of trends, supply chain, green labeling and sustainability DfE, while design tool dimensions include: specifications/customer insights, life cycle assessment (LCA) process, DfE-Material and Part Selection, DfE-Supply Chain, DfE-Manufacturing Impact, DfE-Use Phase Impact, and DfE-End of Life Impact. The IRI Sustainability Maturity Model can be used to measure sustainability process maturity and to benchmark against other sustainability innovation programs; however, a statistically insignificant number of firms to date use this model and each dimension is equal [20].

4. Conclusions

In recent years, sustainability is becoming more important in all aspects of business and supply chains. Companies are developing and implementing strategies to incorporate sustainability

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into the products and services that they deliver to the marketplace. In order to remain in business, every company and its associated supply chain must design and deliver new products. These new products must address the growing sustainability movement. However, NPD incorporating sustainability within SCM is not an easy undertaking.

Based upon experience and a literature review of cases, empirical reviews, and other available literature, recommendations for NPD in SCM [35-37] are relevant today for NPD in SSCM. As outlined above, the managerial recommendations include: top management support and development of an integrated NPD-SSCM strategy, resource allocation, financial support, and support for a common, shared information system; a focus on marketing demands; supplier/customer integration; integrated networks; a coordinated, cross-functional team; and a clear product vision. A single, NPD-SSCM strategy does not exist; however, managers need to consider the specific product, industry, and country factors relevant to their market and supply chains in strategy development.

With respect to economic sustainability, new products that fail to meet the cost-value proposition of the final customer cease to exist in the marketplace. Designers need to carefully analyze sustainable aspects during the design phase, and these sustainability efforts need to continue to be managed throughout the product lifecycle. To be successful, designers should focus on the sustainability requirements of the end customer. Market orientation, green targeting, green positioning, and customer outcomes all influence green NPD. Products – and their companies – that do not meet the economic needs of the end customer will cease to exist. Therefore, economic sustainability is an order qualifier for any new product.

With respect to environmental sustainability, efforts in the past two decades to consider the environmental impact of new products and their associated processes as the product moves through the supply chain have increased significantly. Procedures, such as PLM, DfE, and LCA have all gained in momentum as businesses look to reduce, reuse or recycle their products and associated materials, and reduce the environmental impact of the various processes associated with delivering the product from the raw material supplier to the end customer. However, current research notes that the end customer does not fully recognize the value and is often not willing to pay the additional costs associated with environmentally friendly products. A key recommendation to meet this challenge is to develop market-leading product aesthetic design capabilities geared toward the end customer requirements.

With respect to social sustainability, this is the least researched area of sustainability. To foster, NPD in SSCM, supply chain members should seek other supply chain members with similar socially sustainable values. Trust-building and communication are imperative to developing both internal and external social responsibility surrounding any product and supply chain. Corporate social responsibility toward the local and global communities that surround businesses and their supply chains has also gained momentum in the past decade. Companies have rallied around particular causes, such as the American Cancer Association, or sponsored employee events that give back to society, such as United Way days. To encourage social sustainability with respect to new products, companies need to leverage the brand image that they are creating to foster positive customer perceptions. Similar to environmental sustaina-

bility, when customers do not associate with the social sustainability efforts of the company, they may be less likely to spend more for the new 'socially' sustainable product.

In general, the recommendations and the discussion about each of the three areas of sustainability – economic, environmental and social, all relate to a critical, underlying requirement: the need for NPD and SSCM to focus on end-customer requirements. In order to develop successful products, NPD-SSCM strategies need to address moving environmental and social sustainability into the 'order winner' category for the end customer.

This chapter represents a sampling of significant research efforts in NPD-SSCM that support the continued promotion of the original recommendations for innovative design in supply chains [35-37]. In general, critical failings for this research include a lack of specific data and test cases as confidentiality agreements hinder discloser, and a lack of testing interactions due to difficulties in analysis and interpretation between factors such as industry, quality, cost, timing, and global factors. As indicated at several points in the above discussion, many unanswered questions remain in both the research and practitioner worlds. As noted above, research avenues include: research to address which company oversees and decides upon the final processes and product; how to resolve differences between sustainability visions between partners; how to develop more holistic, relational research in LCA; how to resolve differences in sustainability practices between partners; how to fully incorporate all three dimensions of sustainability into NPD methods such as 3DCE; how to assess and address customer's perceived trade-offs between the three sustainability dimensions; and how to address the varying prices associated with technology for greenhouse gas emission; and how to address different global regulatory issues and the technology choice associated with NPD? Research opportunities abound!

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