A conceptual framework for adopting sustainability in the supply chain

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ABSTRACT

Environmental concerns are intricately linked to various aspects of the supply chain. Awareness of such concerns is reflected in the contemporary business environment and in government legislation. The sustainable supply chain is an emerging trend in industrial development, where it is positioned as business innovation in this research. Based on the research gap identified in a literature map, a conceptual framework was developed using Rogers' [30] *Innovation Diffusion Theory;* with emphasis on the *rate of adoption* and *implementation* of sustainability within a supply chain context. The objective of this work is to strengthen supply chain enterprises' commitment to using this emerging practice in the future. Six research propositions were identified from *Innovation Diffusion Theory*, *Supply Chain Operations Reference* model and *Life Cycle Management* approach.

Keywords – supply chain management, innovation, sustainability

INTRODUCTION

The impacts and consequences of climate change and the imperative to enact a transition to sustainable, low carbon operational practices are important drivers of change in supply chains [6]. Sustainability represents the balanced use of natural, social and economic capital for the continued wellbeing of organizations, the planet and future generations [1] [9] [34]. Corporate sustainability enables enterprises and their supply chain counterparts with the initiatives for a systematic way to reduce energy and environmental wastes, cutting unnecessary materials and regulatory overheads, and generating improved cash flow, all of which are even more important at a time of economic downturn and weak profit margins [52]. The working hypothesis of this research is that sustainability is treated as business innovation, which represents new ideas or changes to current practices that potentially bring radical improvements to existing operations. Moreover, adopting innovative ideas such as new management methods, state-of-the-art production systems, or emerging technology may affect various aspects of supply chain management (SCM): including supply policies, manufacturing operations, inventory and item management, and distribution [8]. SCM comprises a set of integrated approaches that helps manufacturers improve the total effectiveness of planning and operations from procurement of raw materials to producing and distributing the final products. This is achieved through better coordinating of the use of resources in the supply chain - including systems, finance, people and facilities [22][40]. The challenge of building a prosperous and sustainable supply chain underpinned by an acceptable low carbon and other pollutant emissions requires extensive research, networked collaboration and remarkable innovation. Getting new ideas adopted in firms, even when it has obvious advantages, is often very difficult. Moreover, getting new ideas adopted in supply chain enterprises is even more difficult, as firms have different value objectives and unaligned operational processes; even if they appear to be close trading partners [41][42]. Many innovations require a lengthy period of adoption, often of many years, from the time they become available to the time they are widely adopted. The behavioral intention of innovation adopters at the workplace is one of the major influential factors on the rate of adoption [30]. A common problem for many organizations is how to speed up the rate of adoption of an innovation. In this study on sustainability for supply chain enterprises, we attempt to focus our research on manufacturing supply chains, with the major processes defined by SCC [32].

Sustainability is an inherently temporal concept such that its underlying activities may be viable for a short period of time but cannot be carried on indefinitely [19]. While much effort has gone into understanding the triple bottom line of sustainability (economic, social, environmental) rather less has been invested into what is termed the fourth dimension: time [50]. Hansen and Birkinshaw [18] developed the *Innovation Value Chain* framework with the aim to offer an insight to the three main phases of innovation (*idea generation*, *conversion*, and *diffusion*) as well as the critical activities performed during those phases (looking for ideas inside the function; looking for them in other functions; looking for them externally; selecting ideas; funding them; and promoting and spreading ideas companywide). Using this framework, managers get an end-to-end view of their innovation efforts. However, the framework evaluates idea diffusion (i.e. spread of the idea) by assessing market penetration or payback of rolling out new products or businesses (i.e. product or service focus), rather than studying diffusion process in the time dimension. Time dimension is a key element in the process of innovation diffusion, and it is involved as a variable of the (a) *Innovation-Decision Process (IDP)* [30] by which an adopter passes from first knowledge of an innovation through its adoption or rejection, and (b) an innovation's *rate of adoption* in a social system, e.g. an organization, within a given time period [30]. Rogers [30] treated "innovation" and "technology" as synonyms, and positioned *technology*, which may be *hardware*, *software*, or entirely composed of *information*, i.e. information and communications technology (ICT) in today's term, a catalyst in the IDP to enable information seeking and processing with the aim to reduce uncertainty and improve the value of innovations. Sustainability is not merely an inter-organizational issue, but is also an intra-organizational protocol where supply chain activities, which are business-to-business in nature, are encountered in making a contribution to create a low carbon economy. Therefore, an approach to realize corporate sustainability to various SCM processes [32] is necessary. Development and management of supply chains need to respond to the challenges of climate change and the transition to a regulated low-carbon economy [25]. There is a need, therefore, to examine sustainability, drawn from current research and practice, and develop corresponding adoption strategies [13]. Hence, the key questions of this study are: (a) "What is the process of adopting sustainability in supply chain enterprises?", and (b) "What are the influencing factors on the rate of adopting sustainability?" In the forthcoming sections, we present supportive literature, establish a framework on sustainability adoption in supply chain enterprises, and identify propositions and conclusions that may lead to better adoption of this new practice with more desirable implementation outcomes.

THEORETICAL BACKGROUND AND RESEARCH PROPOSITIONS

Sustainability and SCM

The word *sustainability* is derived from the Latin *sustinere* (*tenere*, to hold; *sus*, up). Different dictionaries provide more than ten meanings for sustain, the main ones being to 'maintain', ‘support’, or ‘endure’”. However, since the 1980s sustainability has been used more in the sense of human sustainability on planet Earth and this has resulted in the most widely quoted definition of sustainability and sustainable development, that of the Brutland Commission of the United Nations (UN) (March 20, 1987): “*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*.” At the 2005 World Summit [45] it was noted that this requires the reconciliation of environmental, social and economic demands – i.e. the 'triple bottom line' - have served as a common ground for numerous sustainability standards and certification systems in recent years, in particular in the food industry. However, the triple bottom line as defined by the UN is not universally accepted and has undergone various interpretations. A universally accepted definition of sustainability remains elusive because it is expected to achieve many things in different disciplines.

In this paper, sustainability is associated with Operations and SCM by studying its adoption in the time dimension. The APICS (The Association for Operations Management) Operations Management Body of Knowledge Framework (OMBOK), a premier resource in the areas of production, inventory, materials management, purchasing, logistics, SCM and more, provides definitions on sustainability in the spectrum of Operations management (OM) [1]. OM contributes to good corporate practices by controlling the inputs and outputs, used in the transformation process, which helps enable sustainability as business practices. In this regard, sustainability refers to:

> “…a corporation’s processes, products, and services being aligned in a way that is socially, economically, and environmentally responsible [1].”

Business requires trust and integrity between partners in a supply chain. Sustainability relates to the degree of concern for the environment, including use of renewable resources and minimization of harmful waste where its implementation success much relies on collaboration with supply chain partners. In SCM, sustainability is the idea that:

> “…business can help ensure that markets, commerce, technology and finance advance in ways that benefits economies, societies, ecosystems, and stakeholders in general – or, at a minimum, do no harm—and contribute to a more maintainable and inclusive global economy [1].”

In the context of sustainable supply chains, manufacturers seek clean methods of production, minimization of the environmental footprint of products and services, and combining environmentally friendly decisions with effective supply chain practices [1]. Thus, the term ‘corporate sustainability’ embraces more than the physical environmental factors associated in order to maintain a viable organization [6]. According to APICS [1], the implementation of sustainability in a manufacturing supply chain includes the following major elements:

(a) ***Process innovation*** is to bring new processes and improvements to meet changing market and customers’ needs on sustainability.
(b) ***Clean production*** involves waste minimization and avoidance, reusing waste products when possible, reclaiming products at the end of useful life, preventing or reducing pollution at the source, substituting for toxic and hazardous materials, and reducing waste and potential pollutants in product or service as well as transportation to market.
(c) ***Closed-loop manufacturing*** is a system in which a product is created using renewable energy with no pollutant output and no waste (the materials used in production are

recycled and reused, not discarded).

(d) ***Reverse logistics*** involves planning, implementing, and controlling the flow of materials, finished goods, and related information from the consumer to the producer for the purposes of recapturing value or proper disposal.

(e) ***Sustainable procurement*** or ***green purchasing*** refers to procuring goods and services with less impact on the environment than other products or services meeting similar performance requirements.

(f) ***Life cycle management (LCM)*** manages the environmental aspects and potential impacts associated with a product, process, or service, from the stage of acquisition of raw materials to manufacture, transport, consumer use and disposal, which essentially represents a cradle-to-grave cycle of a product, process or service.

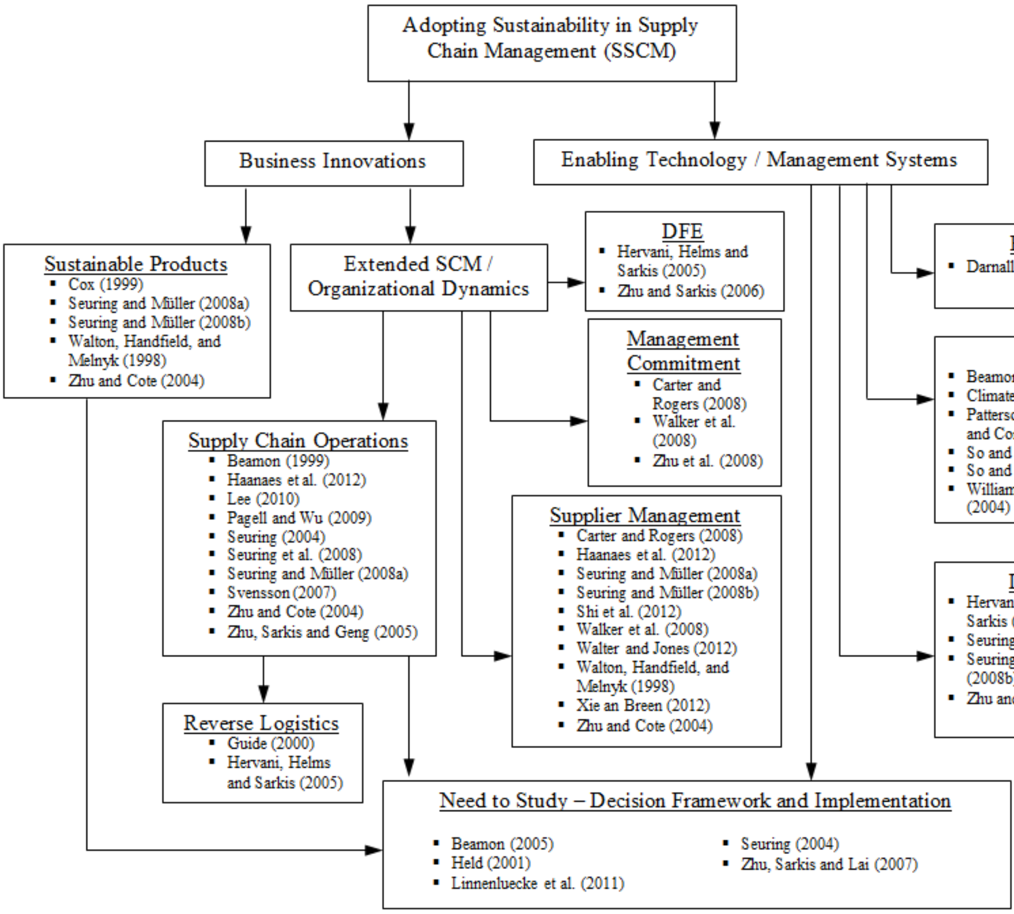

Fig. 1 Literature Map of the Research in Sustainable Supply Chain Management

In order to identify the gap in the literature of this emerging research area, a literature map, as depicted in **Fig. 1**, was developed with the support of 35 relevant and most highly cited articles in sustainable SCM. Two areas that require further research includes: (1) framework to help structure the decisions taken along the supply chain and (2) implementation tactics that help obtain firms' long-term commitment of adopting sustainability as an on-going practice. Based on the identified research gap, a conceptual framework underpinned by relevant contemporary management theory and practices, discussed in the forthcoming section, will be developed as integral to this research.

Supply Chain Operations Reference (SCOR) model for sustainability

A typical manufacturing supply chain has multiple participants, which involves a number of separated but interrelated operational and managerial activities, both upstream and downstream, and along which manufacturers invariably are located centrally coordinating the flow of product, material, information and finance. These activities can be organized into five primary management processes: *Plan*, *Source*, *Make*, *Deliver*, and *Return*, which are originated from the supply chain process model: SCOR [32]. As depicted in **Fig. 2**, SCOR processes extend from supplier's supplier to customer's customer along a supply chain. This involves the operations management areas such as *procurement*, *inventory*, *production*, *transportation* and *orders*. The environmental aspect of the SCOR model provides a structure for defining associated environmental metrics in running and maintaining supply chains in a more sustainable manner through evaluating: *Carbon Emissions*, *Air pollutant Emissions*, *Liquid Waste Generated*, *Solid Waste Generated*, and *Recycled Waste* in an organization's supply chain processes with the aim to improve environment.

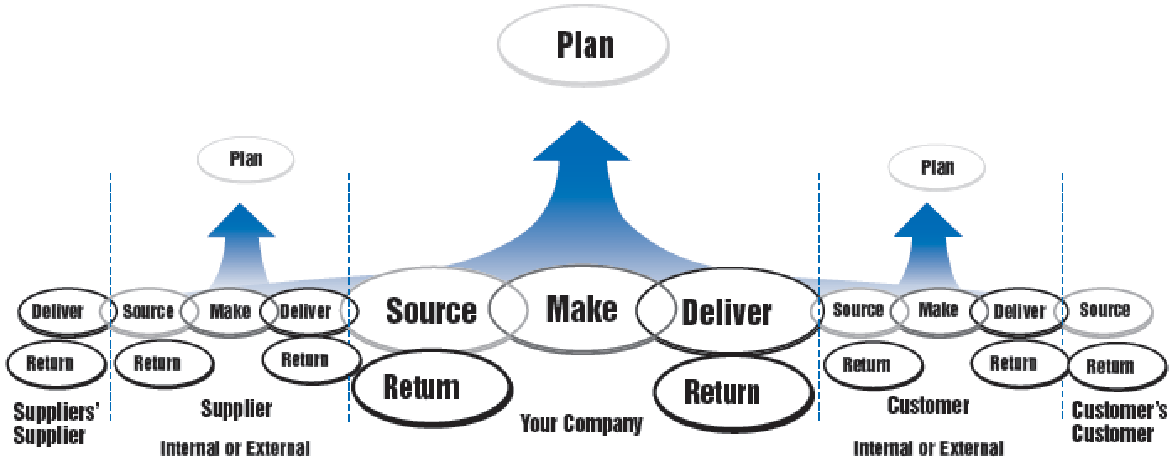

Fig. 2 Supply Chain Operations Reference (SCOR) Model (Adapted from SCC, 2008)

The capability of managing various supply chain activities in a timely and cost effective manner becomes increasingly important to manufacturers in order to stay competitive in their markets. Manufacturers realize that use of appropriate technology is the key to developing this capability [22]. Electronically-enabled manufacturing supply chains (EMSC) offer the potential to achieve the objective by enabling business partners in the manufacturing supply chains to integrate their information resources and to accelerate decision-making in various SCM processes that ultimately enhance efficiency and competitiveness of the firms [41] [42] [51]. With the emergence of ICT and its underlying systems, EMSC become gradually adopted by manufacturers [29] [40]. With EMSC infrastructure in-place, realizing the SCOR model for a sustainable supply chain would become feasible.

Adopting corporate susutainability as business innovation

Implementing sustainability in supply chain enterprises brings radical changes to not only the manufacturing operations but also other areas, such as supplier coordination and selection, which may include implementing associated information systems in various business units and reengineering the day-today activity of all staff members. The profound impact may lead manufacturers to seek reinforcement of their adoption decision. Decision can be reversed if the management is exposed to conflicting messages about sustainability. To support manufacturers making appropriate decisions throughout the entire decision process, a framework, as depicted in **Fig. 3**, can be adopted. Such sustainability practices in the manufacturing supply chain are proposed based on the Innovation Diffusion Theory (IDT) in the time dimension [30].

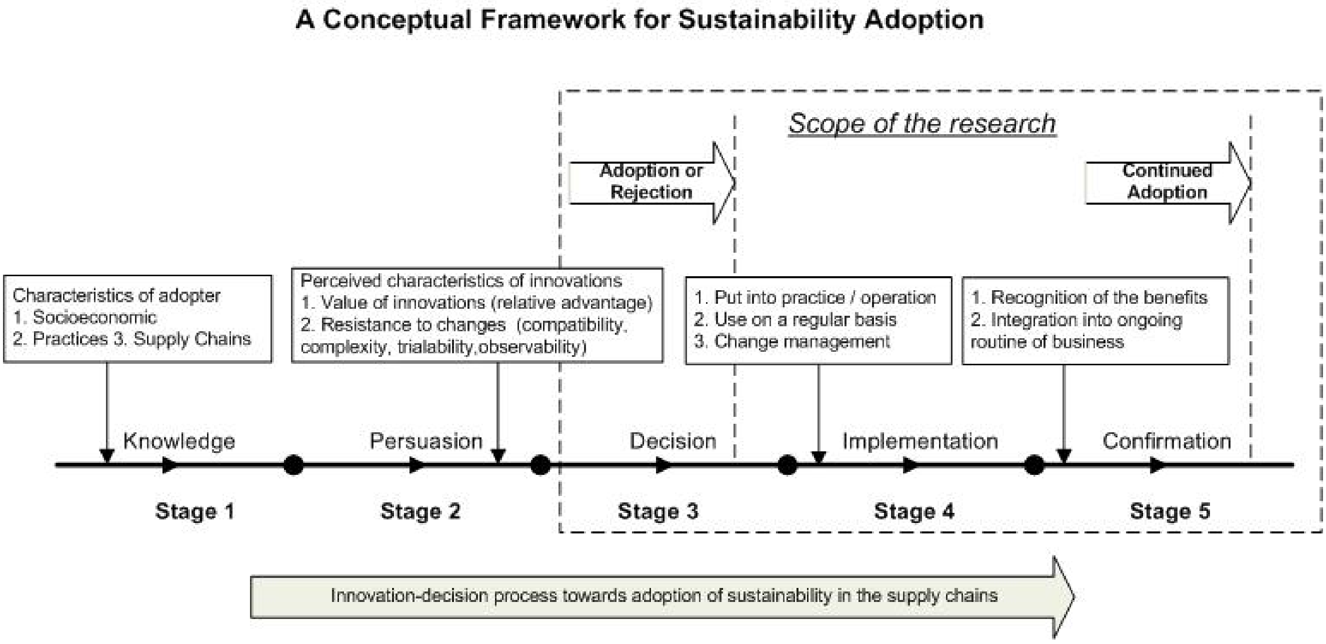

Fig. 3 Conceptual Framework of Sustainability Adoption as Business Innovation in Supply Chain Enterprises (Adapted from Rogers, 2003)

IDT emphasizes that the decision of accepting innovations is influenced by factors that lead to different hierarchy of effects. In order to support supply chain members making appropriate decisions throughout their entire *decision process of sustainability adoption*, Rogers' [30] Innovation-Decision Process (IDP) is used in the study's framework by dividing the decision process into 5 stages: (1) *knowledge*, (2) *persuasion*, (3) *decision*, (4) *implementation*, and (5) *confirmation*, through which an adopter passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision. In this research, the adoption phenomena on the regularization of sustainability in the supply chains that may lead to its ongoing adoption in the long run through overcoming various implementation challenges in stages 4 and stage 5 of Rogers' [30] IDP, are evaluated with the use of SCC's [32] SCOR model.

Theory development and research propositions

The conceptual framework essentially outlines the decision process at various stage of sustainability adoption in supply chain enterprises as an innovation, based on Rogers [30], as depicted in **Fig. 3** This encompasses distinct five stages: (1) *knowledge* stage concerns the awareness of the existence and understanding of sustainability, (2) *persuasion* stage is related to the perceived characteristics of sustainability that lead to the use, (3) *decision* stage leads to adopt or reject sustainability for use in organization, (4) *implementation* stage involves operational and organizational issues to be faced when putting the new idea to use, and (5) *confirmation* stage occurs when the decision-maker recognizes the benefits of sustainability and integrates it as an ongoing practice, i.e. continuous adoption of sustainability as a long-term commitment. The decision process before stage 3 (decision) is about the readiness of end-users and management concerning their perceived values of sustainability and the fear of change and uncertainty (i.e. resistance to change) caused by the adoption of new practices that form an attitude toward it and lead to a decision to adopt or reject sustainability as operations practices. Establishing measures that improve the perceived values, e.g. relative advantage of sustainability could help increase the rate of adoption throughout Rogers' [30] IDP [41][42]. This leads to the first proposition:

P1a ***There is a positive relationship between perceived values of sustainability and the rate of its adoption in a supply chain***

Stage 4 (*implementation*) and stage 5 (*confirmation*) of the framework are related to organizational readiness for implementation in confirming the decision when sustainability is put into regular use. Improving information transparency through implementing improvement methodologies and related ICT systems, e.g. SCOR model and LCM, can reduce uncertainty and the fear of change, leading to the reinforcement of organizational readiness [44][51] that help adaptors recognize the benefits of sustainability, integrate sustainability into day-to-day works, and promote sustainability to supply chain counterparts [30]. This leads to the next two propositions:

P1b ***Resistance to change in sustainability implementation can be reduced by having information transparency***

P1c ***Organizational readiness facilitates the diffusion of sustainability in the supply chain***

The Climate Group [9] argued that industries can make use of modern ICT to move into higher efficiency low carbon markets. The Group has identified several key areas of ICT applications potentially leading to global emissions reductions by 2020 that is five times a firm's own direct footprint. This represents about 7.8 $GtCO_2e$ of emissions savings or 15% of emissions per year. With the emergence of ICT and its underlying systems, relevant ICT applications can be adopted in manufacturing supply chains to help achieve more effective and integrated operations [31][51]. The Group proposed a dematerialization methodology by substituting high carbon products and activities with low carbon alternatives through the use of ICT applications, e.g. replacing face-to-face meetings with videoconferencing, or automating paper-based activities with e-commerce applications, which play a substantial role in reducing emissions in a number of application areas, including: (a) *Online media* – distribute information contents online with the aim of eliminating all CDs and DVDs that contributes an impact of 0.02 $GtCO_2e$ in 2020; (b) *E-commerce* – contribute about 3% reduction in emissions from shopping transport, which is assumed to be 40% of non-work-related private transport, or 20% of all private transport that is equivalent to an impact of 0.03 $GtCO_2e$ in 2020; (c) *Videoconferencing* – assume that 30% of passenger air and rail travel is business travel, and globally 30% of business travel can be avoided through videoconferencing. This contributes an impact of 0.08 $GtCO_2e$ in 2020; (d) *Telecommuting* – the area that ICT substitutions have the most impact with the assumption of work-related car travel in urban and non-urban areas, where the emission can be decreased by 80% leading to a contribution of 0.26 $GtCO_2e$ in 2020.

This leads to ***P2***, which posits that adopting ICT in SCM to support the implementation of sustainability (stage 4) helps not only manufacturers establish a sustainable goal for in delivering products and services that are environmentally friendly, but also dematerializes the supply chains and potentially decarbonizes the economy [9][44].

P2 The application of ICT facilitates the adoption of sustainability in the supply chain

In supporting the implementation of sustainability with the aim of delivering better customer service, cost control, planning and risk management, supplier relationship management, and talent acquisition and development, the SCOR model [32] links performance metrics, processes, best practices, and people into a unified structure. In practice, logistical activities of a supply chain, represented by the *Deliver* processes of SCOR model [32] involve manufacturing firms and their supply chain counterparts, are responsible for much of the environmental cost. Besides, *Source* and *Make* processes that include tiers of supplier, product design, manufacturing and packaging, affect various aspects of the environment: such as waste generations and Greenhouse Gas (GHG) emissions. GHG reduction is a major challenge in the conservation of natural resources as well as for protecting the environment in order to approach sustainable development. The possibilities for reducing the environmental impact of various activities in a sustainable supply chain can be systematically reviewed with the SCOR model [32], and this leads to ***P3a***:

P3a Firms can systematically adopt sustainability in the supply chain through SCOR modeling

In order to conserve natural resources, El-Haggar [14] emphasized cradle-to-cradle concepts to complement the SCOR model. This concept emphasizes remanufacturing and recycling in the LCM processes for dealing with end-of-life products in the supply chains, with *Source*, *Make* and *Return* processes all playing a key role [15]. Implementing reverse logistics in *Return* processes that supports product recovery and goods return to the suppliers is the key to strengthen the capability of waste reduction. Sustainable *Source* processes include green purchasing, which involves an organization assessing the environmental performance of their suppliers, and requires the suppliers to undertake measures that ensure environmental quality in their operational systems [39]. Selecting appropriate suppliers requires manufacturers to develop green purchasing strategies that add environmental, health and safety elements to their sourcing initiatives and serve as an operational resource for procurement staff to understand and pursue green sourcing [53]. Green purchasing strategies involve the acquisition of environmentally friendly or decomposable materials to help reduce the life cycle cost and provide competitive advantage. Suppliers' intention of long-term collaboration and commitment to green practices are the key success factors of green sourcing, which implies that selecting the right suppliers that share similar values is important [39][48][53]. Adopting sustainability in *Make* processes, which include manufacturing, product design and packaging, involves the use of LCM approach by reducing the costs of production and wastes, and to pre-empt any legislation [15][21][39]. Among the *Make* processes, Design for Environment (DFE) is an important process of sustainable supply chains for determining a product's environmental impact at the design phase, which requires not only the availability of *green sourcing strategies*, but also the consideration of efficiency and *eco-effectiveness of the manufacturing process* [21][39]. LCM, representing a cradle-to-cradle philosophy, requires not only adopting sustainability in *Source* and *Make* processes but also the availability of *Return* processes. This eventually forms a closed loop supply chain to uphold sustainability, while on the other hand, relieves the regulatory pressures on waste reduction [21][32][39]. Adopting sustainability in the supply chain through LCM requires firms to develop relevant sustainable practices that assimilate changes into the five primary SCM processes [32], thereby reducing uncertainty and the fear of change. Thus, ***P3b***:

P3b ***Firms can systematically adopt sustainability in the supply chains through LCM***

DISCUSSION

How does any new initiative become accepted in an organization? It often takes significant time and effort before a process, ideology, or strategy becomes an integral part of the business. Many companies pursue operations innovation for good reasons, and that bring radical changes to business mostly struggling with change management, whether that means beginning a new lean program, redesigning a process, or enabling employees to take ownership in key functions. Resistance can occur at every turn: in the teaching of new methods, in adjusting habits and behavior, and perhaps most critically in ensuring that change becomes a lasting part of company culture. However, at least one form of organizational change is taking root in many businesses, i.e. sustainability. Based on an industry survey jointly conducted by MIT Sloan Management Review and Boston Consulting Group, Haanaes *et al.* [17] argued that *corporate sustainability* is on more and more management agendas. The results show that an increasing number of managers and companies are taking sustainability as business practice. There is a notable rise in management interest and the number of companies reporting that sustainability is an important competitive advantage. In the past, the desire to improve the company's image and regulatory concerns, were the primary reasons for adopting sustainability methods and principles. The APICS conducted an industry survey from August through September in 2011 on supply chain sustainability with more than 9000 supply chain professionals [2]. The results indicated that: (a) sustainability is, increasingly, a domain of innovation that is reducing cost by reducing demands on resources, while increasing the reuse of assets that impacts planning resources, processes, capital investing, and strategies, such as lean; and (b) the primary sustainability stakeholders are senior management, first choice, employees, second choice, and third choice, customers; which implies that both producers and end-users are responsible for upholding sustainability within the supply chain context.

The burgeoning awareness of corporate sustainability creates enormous influence on the practices of SCM. In particular, environmental consideration is evident in aspects of products, processes and work behavior in organizations. It might be argued that environmental awareness is the main reason for positioning sustainability as a business innovation in this study. In fact, the radical changes that an implementation of sustainability might bring to the five primary SCM processes [32]: i.e. *Plan, Source*, *Make*, *Deliver*, and *Return*, in association with new operational activities like green purchasing (*Source*), clean production (*Make*), green logistics (*Delivery*) and reverse logistics (*Return*) that need to design and put in operations are the key consideration. The conceptual framework and propositions developed in this paper attempt to allow exploration of the adoption of sustainability in manufacturing supply chains by testing the factors that influence an adopter's decision (stage 3) and long-term commitment (stage 5) from the following 3 perspectives:

(a) *Perceived characteristics of sustainability and information transparency (pre-decision)*
Rogers [30] identified four main elements in the diffusion process by which (1) innovation (sustainability), (2) is communicated through certain channels (five supply chain execution processes in Fig. 1), (3) over time (rate of adoption), (4) among the

members of a social system (supply chain). Identifying perceived characteristics of sustainability helps explain and influence its rate of adoption (theorized as ***P1a***), while committing to information transparency not only undermines unfavorable characteristics such as uncertainty, but also reinforces organizational readiness to facilitate the diffusion of sustainability in the supply chain (theorized as ***P1b*** and ***P1c***). IKEA [28], a Swedish furniture company with over 300 stores worldwide in 35 countries, began its sustainability roadmap in 2000. It launched a code of conduct called 'IWAY' as corporate sustainability standards through the practice of following environmental responsibility in relation to customers, co-workers and suppliers:

- offer *solutions* and *know-how* that help customers live a more sustainable life
- use natural resources in a sustainable manner within *the entire supply chain*
- minimize the carbon footprint from *all IKEA related operations*, and
- be *transparent* to all stakeholders and *communicate* more to customers and co-workers

IKEA embraces information transparency, builds up close relationships with both co-workers and suppliers to share common values and lays down a code of conduct in the IWAY program to extend sustainability to the entire supply chain; which involves 1400 suppliers and 120 thousand co-workers. IKEA's [23] sustainability effort, successfully spans across all major supply chain processes from *Source* to *Make*, *Deliver* and *Return*, which demonstrates long-term management commitment.

(b) *ICT as an enabler of sustainability diffusion in the supply chains (pre-confirmation)*

According to the Climate Group [9], ICT could play a significant role in mitigating global carbon emissions from motorized systems and industrial process optimization, up to 970 MtCO2e in 2020, i.e. about 15% of abatements in the industry. Manufacturing is the 'engine' of China's economic growth and is expected to continue until 2020. But even now it is struggling to cope with the heavy demand on its energy resources. As depicted in **Table 1**, manufacturing accounts for about 47% of China's GDP in 2010, which is the world's number 2 in the share of industry in GDP. ICT has an important role to play in making the industry more efficient. In particular in China, the government was aiming for a 20% increase in energy efficiency by 2010 relative to 2005, through bringing in sustainability initiatives to various industrial segments. In meeting this target, the Climate Group [9] proposed the use of ICT in improving logistics and industrial system efficiency based on the experience of other countries aiming at dematerializing the supply chains in *Source*, *Make*, *Deliver*, *Return* and *Plan* processes (theorized as ***P2***). At the implementation stage, ICT plays a key role with tools for automation, data management, and program management. Its policies can impact data collection, data access, and data management. In addition, there are software packages that are needed for simulation activities before putting the new products, services or practices into live. On the other hand, the application of ICT in the manufacturing supply chain enables the rapid adoption of EMSC. With EMSC infrastructure in-place and supply chain execution process integrated through the SCOR model, implementing reverse logistics system in manufacturing supply chains to support product recovery and goods return in order to strengthen the capability of waste reduction would be feasible [41] [42]. Nevertheless, the success of such system relies on customers' initiatives in supporting environmental protection by delivering their used products to collection points - which triggers the study of consumer attitudes towards the willingness to accept sustainability [41] [42].

GDP Rank	Industry Rank (US$M)	Country	GDP (Apr/2010)	Industry	
				Composition in percentages	Composition US dollar millions
-	-	World	57,937,460	30.6	17,728,863
-	-	EU	16,447,259	25.2	4,144,709
1	1	USA	14,256,275	21.9	3,122,124
2	3	Japan	5,068,059	21.9	1,109,905
3	2	China	4,908,982	46.8	2,297,404
4	4	Germany	3,352,742	26.8	898,535
5	7	France	2,675,951	19.3	516,459
6	6	UK	2,183,607	23.8	519,698
7	5	Italy	2,118,264	25.0	529,566
8	9	Brazil	1,574,039	25.4	399,806
9	10	Spain	1,464,040	26.8	392,363
10	11	Canada	1,336,427	26.4	352,817
11	12	India	1,235,975	28.2	348,545
12	8	Russia	1,229,227	34.8	427,771
13	15	Australia	997,201	26.0	259,272
14	14	Mexico	874,903	32.9	287,843
15	13	S.Korea	832,512	39.4	328,010

Table 1 Nominal GDP sector composition shown in percentage and US$ millions [Source: International Monetary Fund (IMF), *World Economic Outlook Database, April 2010: Nominal GDP list of countries; Data for year 2009*.]

(c) *Improvement methodologies and sustainability diffusion (post-confirmation)*

The SCOR model [22] positions each supply chain as a "Chain" of *Source*, *Make* and *Deliver* execution processes. Execution processes transform or transport materials and/or products, while each process is a customer of the previous process and a supplier to the next, i.e. *Source* processes very much follow the business rules set-out in *Make* processes, and likewise *Make* and *Deliver* processes. The SCOR model ties emissions to supply chain processes, providing a structure for measuring environmental performance and identifying where performance can be improved, which help manufacturers adopt sustainability to the supply chains in a systematic manner (theorized as ***P3a***). Ensuring total green operational processes covering *Plan*, *Source*, *Make*, *Deliver* and *Return*, requires long-term commitment to invest in sustainability involving not only (a) *resources*, such as people and systems, but also (b) *time*, to build relationship with *suppliers* and the trust of *staff* and *customers* on the new practices [39][48], which is essentially a diffusion process. Stubbs [43] argued that a sustainable enterprise cannot achieve the green mission on its own, but needs to collaborate with its supply chain partners, especially suppliers, through a systematic way to eliminate waste, benign emissions, adopt renewable energy and recycling products. As with the SCOR model, LCM is an improvement methodology that manages total product life cycle from initial design, right through the supply chain, helps manufacturers to collaborate with different stakeholders in making the supply chain more sustainable (theorized as ***P3b***).

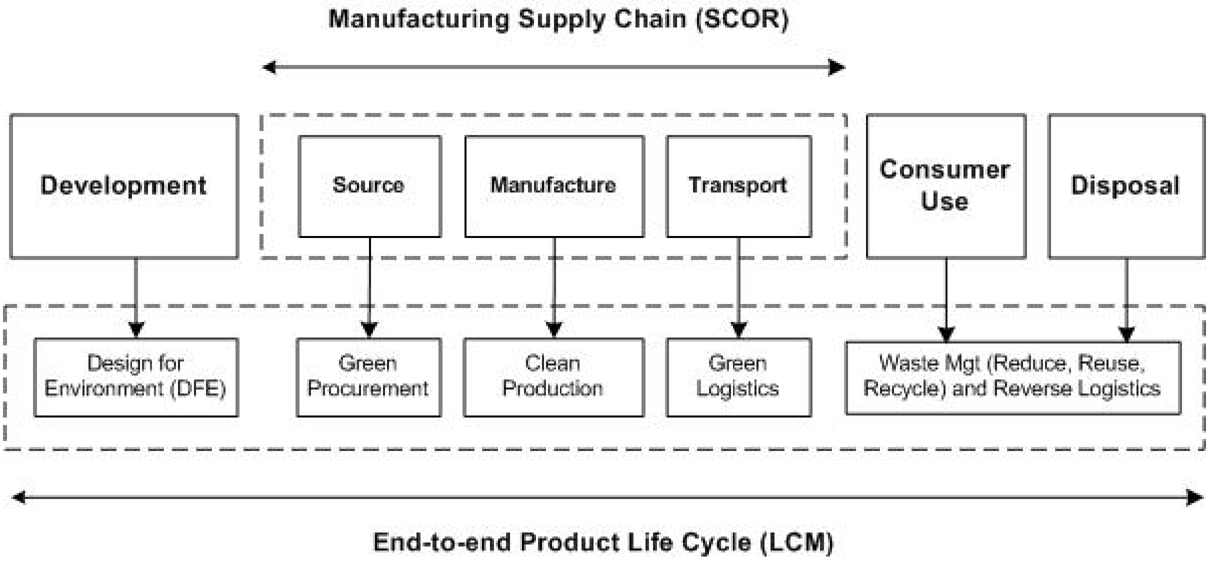

Fig. 4 SCOR and LCM in an extended supply chain (Adapted from Fiksel, 2009)

Based on the conceptual framework, factors in persuasion stage (stage 2) and implementation stage (stage 4) that might influence an adopter's decision (stage 3) and long-term commitment (stage 5) of adopting sustainability as on-going practices in a supply chain are initially accessed, and which will be further explored in future study. At the persuasion stage and at the decision stage, the decision making unit seeks evaluation information, messages that reduce uncertainty about sustainability's expected consequences (information transparency facilitates the seeking process), develops a general perception on the sustainability (over its perceived characteristics) and forms a favorable or unfavorable attitude toward it. According to Rogers [30], the IDP has been strictly mental exercise of thinking and deciding, until the implementation stage where at this stage, adopters may encounter countless operational problems and may disparately seek all possible solutions to fix them. This may also involve overt behavior change as sustainability put in practice, which can be influenced by how adopters approaching these problems and outcomes of implementation. Implementation may continue for a lengthy period of time, until a point is reached eventually at which sustainability becomes institionalized as a regular part of an adopter's ongoing operations, i.e. stage 5.

In order to implement sustainability satisfactory, it is inevitable that the principles of LCM are applied to adopt the cradle-to-cradle approach [14]. As depicted in **Fig. 4**, LCM considers for products all life cycle stages and for organizations the complete supply chains, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal [46]. Through such a systematic overview and perspective, the unintentional shifting of environmental burdens, economic benefits and social well-being between life cycle stages or individual processes can be identified and possibly avoided. Manufacturers may want to incorporate LCM thinking in their sustainability strategies with the concept of an extended supply chain and to become more socially responsible by including non-manufacture phases, i.e. *consumer use* and *product disposal*. Unger *et al*. [46] argued that majority of the GHG that impacts on fast moving consumer goods (FMCG) do not occur in the manufacturers' own operations. As much as 68% of GHG impacts occur at the consumer-use phase, while less than 5% of the impacts occur at the phases of manufacture (3%) and transport (2%). Reducing the contribution from the consumer phase and disposal phase is a significant challenge since these life cycle phases are not under the direct control of manufacturers. However, it is acknowledged that a life cycle perspective has to be taken to facilitate the diffusion of sustainability in an extended supply chain and therefore all opportunities need to be explored. Lee [24] stressed that radically changing the manufacturing processes in order to make the product greener is not sufficient and manufacturers need to treat sustainability as a core operational issue through examining their extended supply chains. For example Hewlett-Packard, Electrolux, Sony, and Braun, which are rivals in the consumer electronic product industry, joined forces and formed the European Recycling Platform (ERP), which has cut manufacturers' recycling and disposal costs by as much as 35% in countries where they operate. Sustainability is important for many businesses but managing impacts can be challenging with today's global supply chains. Invariably there are many stakeholders involved, and its successful implementation requires senior management's commitment to facilitate inter- and intra-supply chain collaboration [32].

CONCLUSIONS AND FUTURE RESEARCH

The purpose of this theory building exercise was to provide a conceptual framework for guiding researchers through a systematic process to explore factors that influence the decisions and long-term commitment of adopting sustainability in manufacturing supply chains. The overall aim of such initiatives (innovative intervention) is to reduce the environmental impact without sacrificing commercial performance. The goal of this study is to provide firms with insights on implementing and adopting sustainability in the supply chain and to strengthen their commitment to using this emerging practice. A literature map was developed to help identify the research gap of this emerging area. Thus, a conceptual model was proposed based on Rogers' [30] IDP, with emphasis on improving (a) the rate of adoption (influence stage 3: *decision*) and (b) implementation (influence stage 5: *long-term commitment*) through upholding information transparency and reinforcing organizational readiness. Six research propositions were developed to theorize the concepts of sustainability adoption in the supply chain based on IDT [30], SCOR [32], and LCM [14] with ICT as technology enablers. The SCOR/LCM approach is recognized as organizational improvement methodologies, but post significant influence on the regularization of sustainability as an on-going practice in supply chains. Moreover, the study triggers future research. It is envisaged that a comparative study will be conducted on the adoption of sustainability in manufacturing supply chains by comparing global companies from high industry rank countries (See **Table 1**) and local companies. The results are expected to help accelerate sustainability adoption when designing and developing supply chains within manufacturing firms.

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