Journal of Cleaner Production 16 (2008) 1688–1698

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

An exploration of measures of social sustainability and their application to supply chain decisions

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ARTICLE INFO

Article history:
Available online 11 July 2008

Keywords:
Sustainability
Corporate social responsibility
Supply chain
Decision-making

ABSTRACT

Sustainability recognizes the interdependence of ecological, social, and economic systems – the three pillars of sustainability. The definition of corporate social responsibility (CSR) often advocates ethical behavior with respect to these systems. As more corporations commit to sustainability and CSR policies, there is increasing pressure to consider social impacts throughout the supply chain. This paper reviews metrics, indicators, and frameworks of social impacts and initiatives relative to their ability to evaluate the social sustainability of supply chains. Then, the relationship between business decision-making and social sustainability is explored with attention initially focused on directly impacting national level measures. A general strategy for considering measures of social sustainability is proposed, and a variety of indicators of CSR are described. Several of these indicators are then employed in an example to demonstrate how they may be applied to supply chain decision-making.

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1. Introduction

Globalization and outsourcing have increased the complexity of supply chains. Concurrent with this trend, over the past few decades, the concepts of sustainability and sustainable development have emerged as humanity has become more cognizant of its increasing impact on the world. The World Commission on Environment and Development (WCED) brought the concept of sustainability to global prominence in *Our Common Future* (or the Brundtland Commission Report) that described sustainable development as meeting "the needs of the present without compromising the ability of future generations to meet their needs" [1]. The United Nations (UN) has repeatedly demonstrated its commitment to sustainability through efforts such as Agenda 21 [2] and the Millennium Development Goals [3]. Furthermore, sustainability has been integrated into the mission of numerous organizations and institutions, from local to international in scale [4].

The interrelationships among society, the environment, and economic/industrial development are integral to the concept of sustainability. In order to achieve sustainable development in both industrialized and developing nations, we must characterize the connections and interactions among these three "pillars" of sustainability. This is because a balance among the pillars cannot be achieved without an adequate understanding of how societal and industrial actions affect the environment or how today's decisions may impact future generations. Therefore, increased knowledge and awareness of the issues encompassed by sustainable development are needed.

One of the principal challenges of sustainability is to make the Brundtland definition operational, that is, use it to guide decisions. An alternative definition of sustainability [5] begins to provide some assistance on the issue: "[design and operation of] human and industrial systems to ensure that humankind's use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment." This definition makes it clear that metrics, or measures of performance, are needed in order to judge the efficacy of any decision on the resulting sustainability.

It is common practice for decision-makers to address the economic pillar of sustainability, and over the last decade, increasing effort has been directed at the environmental pillar through attention to environmental life cycle impacts. Until recently, however, the pillar associated with the social dimension of sustainability has not been well-defined. Discussion of this element has received little attention in the literature, and when discussed, has emphasized legislative issues or human health and safety rather than the cultural and ethical ramifications of decisions [6,7,8]. The Brundtland report concedes the extraordinary pressure that developing countries are under to exploit their environmental resource base for economic gain. The report highlights the difficulties facing developing countries whose economies rely heavily on their natural resources. This suggests that developing countries focus largely on economic benefits, perhaps at the expense of the

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0959-6526/$ – see front matter Published by Elsevier Ltd.
doi:10.1016/j.jclepro.2008.06.001

environment. What often do not appear to be considered, however, are the concomitant social effects.

The concept of corporate social responsibility (CSR) also acknowledges the importance of the social dimension of sustainability. While the Brundtland definition of sustainability is widely known and generally accepted, at the very least as a starting place in constructing a definition for sustainability, rigorous definitions for corporate social responsibility and social sustainability have yet to be established. There are strong linkages between the concepts of sustainability and CSR. Many definitions of CSR include references to ethical behavior related to the environment, society, and the economy [9].

Another principle of CSR is conducting business in a way that is consistent with the morals and values of society, but "not necessarily required by law" [10]. Some have argued that the only social responsibility of a business organization is to deliver profits to its owners/shareholders [11]. However, although economic responsibilities are fundamental to business, society often has a number of other expectations for businesses. Companies are frequently institutional mainstays within communities, supporting such discretionary activities as philanthropic donations, healthcare, childcare, and educational opportunities. Carroll [12] suggests that these societal expectations are in fact social responsibilities, and that corporations must assume a wide range of economic and social (e.g., legal, ethical, and discretionary) responsibilities.

A company seeking to operate in accord with the principles of sustainability or taking an ethical or citizenship approach to corporate social responsibility must consider its entire supply chain, "not just those links which belong to its own sphere of legal responsibility" [13,14]. Addressing sustainability and CSR (as commonly defined) requires consideration of environmental, economic, and social impacts throughout the life cycle of the product. To ensure that more environmentally and socially responsible decisions are made, decision-makers require tools that facilitate a more complete understanding of potential impacts.

This paper explores issues and methods that corporations should consider in their efforts to undertake actions that are socially sustainable, especially with regard to supply chain decisions. Section 2 elaborates on the topic of social sustainability: metrics and indicators of social sustainability and corporate social responsibility, the nature of supply chains, and initiatives to evaluate the sustainability of supply chains. Then, input–output modeling is examined as a technique to assist in the selection of a supplier in order to positively affect a measure of social sustainability. A variety of potential measures of social impacts are then suggested, and a discussion of their relative strengths and weaknesses is provided. A method is proposed to characterize the social sustainability of a given supply chain, and an example is presented to demonstrate the method.

2. Background

A supply chain is made up of a number of companies, and the sustainability of the chain is dependent on the sustainability of the individual companies. To address the sustainability of a company, consider Fig. 1, which displays the four fundamental flows into and out of a corporation. Some would argue that the purpose of a business is to reconfigure physical substances, human resources, information, and financial resources in such a way so that the financial resources that exit the system are larger than those that enter. Sustainability requires that corporations maintain the integrity of social and environmental systems while undertaking this reconfiguration. One of the challenges associated with integrating the three pillars of sustainability into decision-making is clarifying the boundaries between interrelated environmental, social, and economic impacts [14–17].

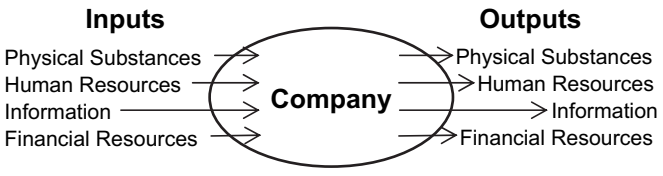

Fig. 1. Primary flows of a corporation.

2.1. Tools to support environmental sustainability – life cycle assessment

There are a number of approaches to inter-organizational management that support sustainability, including industrial ecology, life cycle management, integrated chain management, and green/environmental/sustainable supply chain management [18]. Each of these concepts is concerned with the environmental impacts of material flows within a specified system boundary and timeframe. A life cycle assessment (LCA) can provide information related to the impacts of a product or service. An LCA considers such life stages as raw material extraction, material processing, manufacturing, distribution, use, and disposal options (e.g., recycling). As noted above, pursuit of sustainability requires an inclusive view of impacts across the life cycle, and environmental life cycle assessment is becoming an increasingly effective tool for determining ecological impacts. Life cycle costing (LCC), though not fully developed, seems to be a likely candidate to address the economic impacts of products and services across their life cycle; Norris [19] provides a comparison of environmental LCA and LCC. A few attempts have been made to construct social life cycle assessment (SLCA) tools, which integrate social impacts into LCA, but these efforts have tended to focus on social measures that are closely linked to environmental issues (e.g., human health) as opposed to the impacts on the culture and institutions of a society.

The ISO 14000 series establishes the standard method for considering the environmental impacts of a product or service throughout its life cycle. This framework consists of four fundamental steps: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation [20]. The input and output flows of a corporation can be thought of as being composed of various inventory data categories. For an environmental LCA, emphasis is placed on how physical substances flow and change chemically. For example, ozone depletion, smog formation, and acidification could be categories of environmental impacts associated with emissions. Inventory data, such as CO_2, SO_2, and NO_x emissions could be classified into impact categories and characterized based upon cause and effect relationships. These well-understood and commonly modeled relationships are shown with solid arrows in Fig. 2. Other potential inventory data and relationships are shown with dashed lines.

There is an ongoing debate among LCA practitioners regarding the use of midpoints vs. endpoints in the third step of LCA, life cycle impact assessment (LCIA). Midpoint indicators are defined as "a parameter in a cause–effect chain or network (environmental mechanism) for a particular impact category that is between the inventory data and the category endpoints" [21]. Scientists have developed many accurate models and tools describing impact pathways – the causal relationship between the emission (or inflow) of a substance and the impact on an entity (e.g., ozone layer depletion and global warming potential) [22]. One of the advantages of using endpoint categories is that they are often more relevant to decision-makers; however, midpoints tend to be more comprehensive and more certain [21]. Midpoint indicators may impact a variety of endpoint indicators, but these impact pathways

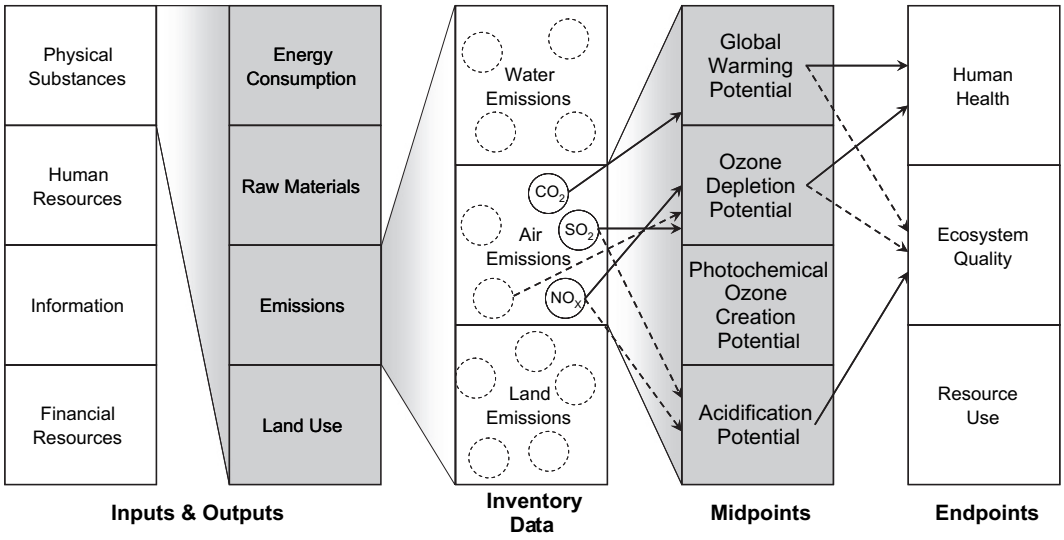

Fig. 2. Portion of the category hierarchy for an environmental LCA (adapted from [21,23,24]).

are not necessarily modeled or known. Many modelers use midpoint values as starting points in the calculation of endpoint responses. For example, the LCA tool Eco-indicator 99 focuses on damage to three endpoints: human health, ecosystem quality, and resource use [23]. For this tool, CO_2 and CH_4 emissions can be used to estimate the "climate change potential," a midpoint category, and this category in concert with other midpoint values can be used to make a statement about "human health," an endpoint category.

The ISO life cycle standard provides a useful tool to facilitate consideration of the broader impacts of industrial activity and decisions. However, until recently, the scope of life cycle assessment has generally been limited to environmental impacts. In order to address sustainability, economic and social issues must also be considered. There has been a global movement toward increased use and relevance of LCA [25]. The United Nations Environmental Program (UNEP) has partnered with the Society of Environmental Toxicology and Chemistry (SETAC) in a Life Cycle Initiative. The mission of the initiative is "to develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire life cycle to achieve sustainable development" [25]. One outcome from the initiative is a recommendation to incorporate socio-economic aspects in life cycle management [16]. Furthermore, the initiative has proposed a number of "cross-cutting" task forces, the aim of which is to address issues that have been identified as relevant in the overall user needs assessment and concern more than one program. Interestingly, only one cross-cutting task force has been instituted – its objective is integrating social aspects in LCA. More recently, the work of the UNEP–SETAC Life Cycle Initiative has indicated that further efforts are needed to include social considerations because "so far, the social and ethical dimensions of sustainability have not been given the same attention within the business community since the benefits are less tangible" [26].

2.2. Tools to support social sustainability – social life cycle assessment

There have been a few efforts directed at integrating social aspects into a life cycle format in the past decade. Most notable are O'Brien et al. [27], Schmidt et al. [28], Dreyer et al. [29], Hunkeler [30], and Norris [17]. The approach of O'Brien et al. [27] supplements environmental LCA by identifying social and political factors that contribute to environmental issues. One of the key elements of this approach is analyzing the environmental inventory and impacts to determine the "controls over, organization of and actions in the life cycle". In this way, the connection between environmental impacts and social, cultural, and political structures are emphasized.

The framework suggested by Dreyer et al. [29] seeks to become a corporate decision-making tool and incorporates the impacts of products and services on people, specifically promoting human health, human dignity, and basic needs fulfillment. The authors advocate use of a two-tiered approach, including an obligatory portion guided by universal and local/country norms and an optional portion, which would allow parameters of special interest or relevance to be included. Subjectivity related to the inclusion of social impacts would be revealed by leveraging the emphasis on transparency within the ISO LCA framework, which requires appropriate documentation of the information underlying the LCA (e.g., assumptions, data sources and quality).

Norris [17] proposed a methodology to examine the benefits and damages to human health due to changes in gross national product (GNP) per capita and the associated changes in pollution production. To address some of the weaknesses of this methodology, Norris also suggested the inclusion of attribute data, such as Fair Trade certification, in LCA. Attribute data may be equivalent to the "parameters of special interest" suggested by Dreyer et al. [24].

Hunkeler [30] and Schmidt et al. [28] both seek to integrate social considerations to existing environmental analysis, but take different approaches. Hunkeler's technique is based upon existing life cycle inventory data and uses a framework similar to that of environmental LCA. Ultimately, it enables product comparisons using regional level data to identify differences in employment per functional unit relative to work hours required to meet basic needs. Schmidt et al. [28] propose a method to perform and present "socio-eco-efficiency" analysis that corresponds to BASF's eco-efficiency analysis and compares environmental and social performance to economic costs. They suggest that social metrics could be developed from industrial sector assessments.

From this literature, three key concepts emerge. First, the movement toward a social life cycle assessment tool is influenced by the success of environmental LCA. Second, the impact pathways between corporate flows (i.e., inputs and outputs) and socially oriented midpoints and endpoints are unclear. Some relationships have been identified, but it appears that there are numerous interrelated variables that may be important and are not yet

functionally linked within the constructs of LCA. Third, the consideration of social impacts requires, at a minimum, some modification to the environmental LCA methodology. With these concepts in mind, it may be useful to extend the classification and characterization process associated with environmental life cycle assessment (Fig. 2) to construct a similar figure for social life cycle assessment (Fig. 3).

Fig. 3 has a structure similar to that of Fig. 2 but differs in several respects. Let us refer again to Fig. 1, which displays the primary flows of a corporation: physical substances, human resources, information, and financial resources, and consider how these flows relate to a category hierarchy for a social life cycle assessment. As we move from left to right in Fig. 3, the next area to address is inventory data. In constructing the figure, we need to identify and inventory items of social importance, as well as relevant mid and endpoints. A review of potential indicators and midpoints for social sustainability is provided in Section 2.3. Impact pathways or transport mechanisms from inventoried data to mid and endpoints are also needed. As noted above, a few methods for mapping social inventory data into mid and endpoints have been proposed, but much work remains to be performed in this area. As in Fig. 2, solid and dashed lines in Fig. 3 represent the known and unknown items of importance in social life cycle assessment, respectively.

As is evident, several mid and endpoints have been displayed in Fig. 3; however, the limited number of categories that are proposed represent only a starting point for further discussion on a comprehensive set of categories. The Millennium Development Goals [3] suggest that attention should be paid to both basic and higher needs. These goals promote meeting more basic needs through reductions in poverty, improvements in human health, and ecosystem protection, but also consider higher level needs such as those associated with education and gender equity. Initially, corporations may seek to address sustainability or CSR by meeting the basic needs of their employees and the communities they interact with. Companies that seek to be deeply sustainable may wish to foster social impacts that enable people to go beyond meeting their basic needs – these higher order needs may be captured via endpoints such as safety, quality of life, and equity.

2.3. Measures of social sustainability

One of the fundamental questions that must be answered if we are to move forward with a life cycle assessment tool for social sustainability is: what impacts should be considered? A consensus has not been reached regarding the measurement of sustainability. Parris and Kates [31] reviewed 12 efforts to define indicators of sustainability, ranging in scale from global (e.g., UN Commission on Sustainable Development) to local (e.g., the Boston Indicators Project). The initiatives identified from 6 to 255 indicators of sustainability. These indicators vary greatly in terms of the level of control that business decision-makers have over them, the effort required to incorporate them into decision-making processes, and the financial burden associated with their implementation. In order to clarify how sustainability indicators are organized and how social sustainability might be measured we will briefly compare two sustainability frameworks. The first of these frameworks, adopted by the United Nations Division for Sustainable Development (UNDSD), measures progress toward sustainability via indicators that are tied to the Millennium Development Goals and the other, the Sustainability Reporting Guidelines, emphasizes sustainability reporting with a focus on standardization and procedures.

The UNDSD theme/sub-theme framework was established to organize and select indicators of sustainable development [32]. This framework classifies indicators first by the primary dimension of sustainable development (social, environmental, and economic), then by theme (e.g., education), and finally by sub-theme (e.g., literacy). The themes within the social dimension of sustainable development are: equity, health, education, housing, security, and population (see Table 1). Each of the sub-themes has at least one, and as many as three quantifiable indicators associated with it. These indicators may be especially useful because reports from the Human Development Report Office of UNEP provide national and regional level data for the indicators for many countries.

The Sustainability Reporting Guidelines were developed in conjunction with numerous stakeholders, including businesses, non-profit groups, investor organizations, and trade unions. The effort was led by the United Nations Environment Programme (UNEP) and the Coalition for Environmentally Responsible Economics (CERES), a non-governmental organization in the United States [33]. This framework, like that of the UNDSD, organizes indicators into a four-tired hierarchy. However, the levels are termed areas (social, environmental, and economic), categories (e.g., human rights), aspects (e.g., non-discrimination), and indicators (e.g., a description of global policy and procedures/programs preventing all forms of discrimination in operations, including monitoring systems and results of monitoring). The framework also differentiates between "core" and "additional" indicators – core indicators are those most pertinent to reporting organizations and stakeholders, other

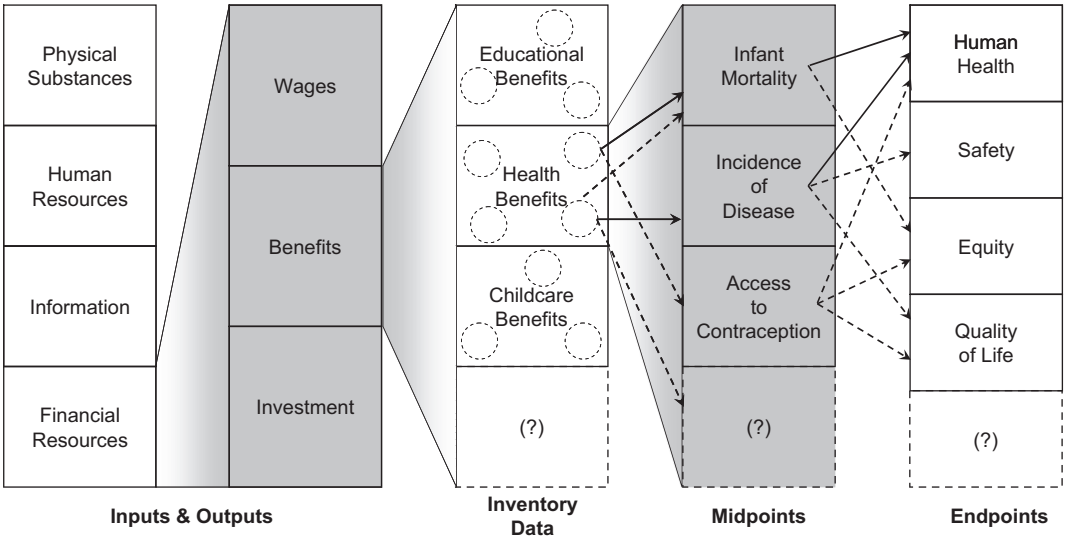

Fig. 3. Portion of category hierarchy for a social LCA.

Table 1
UNDSD theme/sub-theme framework for social dimension of sustainability [32]

Theme	Sub-theme	Indicator
Equity	Poverty	Percent of population living below poverty line
		Gini index of income inequality
		Unemployment rate
	Gender equality	Ratio of average female wage to male wage
Health	Nutritional status	Nutritional status of children
	Mortality	Mortality rate under 5 years old
		Life expectancy at birth
	Sanitation	Percent of population with adequate sewage disposal facilities
	Drinking water	Population with access to safe drinking water
	Healthcare delivery	Percent of population with access to primary healthcare facilities
		Immunization against infectious childhood diseases
		Contraceptive prevalence rate
Education	Education level	Children reaching grade 5 of primary education
		Adult secondary education achievement level
	Literacy	Adult literacy rate
Housing	Living conditions	Floor area per person
Security	Crime	Number of recorded crimes per 100,000 population
Population	Population change	Population growth rate
		Population of urban formal and informal settlements

indicators are labeled "additional." Although one of the primary goals of this effort was to enhance the rigor of sustainability reporting, a majority of the social indicators are subjective and qualitative. For example, the health and safety aspect within the labor practices and decent work category contains the following core indicators:

- practices on recording and notification of occupational accidents and diseases, and how they relate to the ILO Code of Practice on Recording and Notification of Occupational Accidents and Diseases,
- description of formal joint health and safety committees comprising management and worker representatives and proportion of workforce covered by any such committees,
- standard injury, lost day and absentee rates and number of work-related fatalities (including subcontracted workers), and
- description of policies or programs (for the workplace and beyond) on HIV/AIDS.

Descriptions of corporate activities, like many of the indicators within the Sustainability Reporting Guidelines, are informative. Unfortunately, it is frequently problematic to incorporate such qualitative data into the decision-making tools often required by business.

Labuschagne et al. [34] sought to improve business sustainability assessment by proposing a framework of indicators that incorporates criteria from a number of key frameworks, namely: United Nations Commission on Sustainable Development Framework, Global Reporting Initiative, Sustainability Metrics of the Institution of Chemical Engineers, and Wuppertal Sustainability Indicators. It was concluded that the criteria for social sustainability within these frameworks were not "efficient;" as a result, eight supplemental guidelines and frameworks were reviewed to identify additional critical indicators for social impact assessment and corporate social responsibility in order to complete the social dimension of the framework. In continued pursuit of social sustainability criteria, Labuschagne and Brent [35] later reviewed 31 frameworks, guidelines, and standards related to social impact assessment, corporate social responsibility, and other formal applications of the societal/business relationship. They developed a framework to classify measures of social sustainability and found it to be applicable in 10 case studies. Additionally, using the Delphi Technique, they determined that many of the social impact criteria are best integrated at the corporate level, opposed to the project level.

Tsuda and Takaoka [36] have proposed a comprehensive sustainability index, the "gross social feel-good" (GSF) index. The GSF index is composed of six component indexes, focused on the environment, economy, safety, health, comfort and happiness. The emphasis of their work is on the safety, health, and comfort indexes. However, their happiness index is intriguing as it begins to address the higher order needs (e.g., love and belonging, esteem, and self-actualization) suggested by Maslow [37]. Tsuda and Takaoka recommend evaluating the happiness index with survey techniques such as questionnaires, conjoint analysis, and contingent valuation. Although this type of information is useful, it may be challenging to incorporate into assessment tools such as life cycle analysis. When Labuschagne and Brent [35] attempted to determine the "social footprint" (analogous to "environmental footprint") associated with three projects, using their own metrics, they could not calculate all of the social midpoint category indicators they proposed. This indicates that many of proposed frameworks for social sustainability or corporate social responsibility could be difficult to incorporate into decision-making. Section 2.4 addresses some of the challenges associated with decision-making for supply chains.

2.4. Business decisions related to supply chains

Buyer–seller relationships have transformed in recent years. Firms are moving away from adversarial relationships toward stronger relationships with fewer suppliers [38]. In these long-term partnerships, a company may often ask a supplier to not only manufacture, but also to design components. In addition to price, many other measures are now being used to select suppliers, such as quality, delivery, and service [39]. We are now at the point, where a company must not only select their direct suppliers, but also consider the entire supply chain or network to meet the demands of a global market.

A harmonized system of people, organizations, information, activities, and resources involved in providing a product or service is frequently referred to as a supply network. The use of the term "network" suggests that supplier facilities can be described with nodes, distribution links characterized with arcs that connect the nodes, and the OEM (original equipment manufacturer) or enterprise positioned as the terminal node in the network. Each node in the network adds value for subsequent customers through the manufacture and delivery of products. Flow within the supply network can involve a variety of materials including both finished components and work-in-process, and the use of the term "network" suggests a highly interconnected system of nodes perhaps achieved via advanced IT or web-tools [40,41]. The network, which begins with unprocessed raw materials, and ends with a finished product (and includes suppliers, manufacturing centers, distribution centers, and retail outlets), is referred to as a supply chain [42,43].

Supply chain management or decision-making increasingly emphasizes an enterprise focus on core competencies with the effect being an increase in the number of organizations involved in the supply chain and, with this increase in complexity, reduced enterprise control of logistical issues. Some of the traditional supply chain related decisions include [43]:

- 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?

Current issues of interest with respect to supply chains include the application of lean principles that encourage the focus on demand chains. Some attention has been devoted to evaluating the sustainability of supply chains [44,45], but has largely emphasized environmental sustainability. One of the principal challenges associated with supply chain decision-making is selecting suppliers that follow the same guiding principles with respect to sustainability as the enterprise [46].

3. Effect of business decisions on social sustainability

As Section 2.4 described, one of the principal supply chain decisions is the selection of a supplier. Given the desire to establish a supply chain that is socially sustainable, as a first step we must evaluate companies in terms of their social impacts. In considering the social impacts of corporate actions, Fig. 4 shows the interaction between a company and its stakeholders. The company provides its employees with wages, and the employees, in turn, provide the company with labor, skill, and/or expertise. The company may also positively affect its employees (and their families) by providing healthcare, childcare, and education. The basic exchange between a company and its suppliers is money for goods or services. There may also be opportunities for each of the stakeholders to have a role in guiding the values of the company; likewise, the company may help to shape the values of its stakeholders. For example, if a large company were to require a certain level of social responsibility from its suppliers, there would be increased incentive for members of this industrial sector to compete to reach this level of social responsibility. Many companies have already compelled their suppliers to attain improved environmental performance (see for example, [47]). In addition, the community and larger society may establish laws and regulations that must be met by the company. The company may contribute taxes, infrastructure, or philanthropic gifts to these outside stakeholders. Owners (or shareholders) invest financial capital in the company and the company may return some funds in the form of profits (or dividends). The social issues associated with ownership include financial accountability. Recent examples where companies have displayed a lack of social responsibility to the owners include activities at Enron, ImClone, and Global Crossing.

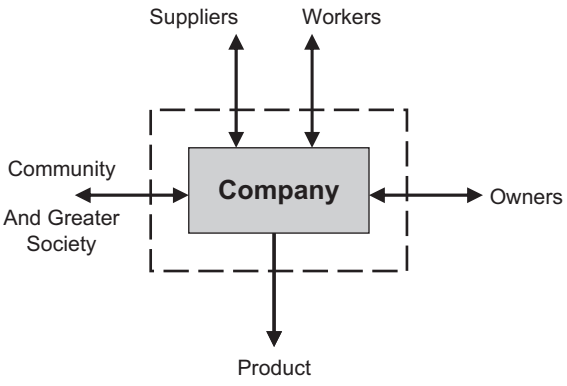

Fig. 4. Boundary for assessing social performance of a company.

Identifying the boundary condition for an assessment of social impacts is important because of the linkages between suppliers and scales (e.g., communities, regions, countries). For example, identifying a correlation between educational, on-site childcare, and improved literacy rates among employee's children would be possible with adequate data resources. However, the impact pathway from corporate taxes to improvements in national literacy rates is complex at best and indiscernible at worst. Similarly, establishing the social impact associated with a given product or service due to the actions, policies, and choices of all the suppliers contributing to it can be an arduous task. There is considerable need for better understanding of the causal relationships between corporate activities and social impacts in the greater society, in order to fully address the call for sustainable development.

3.1. Corporate social impacts

Perhaps the first question that must be addressed in assessing the social sustainability of a corporation is which social impacts or indicators should be considered? Dreyer et al. [29] addressed this issue by suggesting obligatory and optional components. Another noteworthy issue is that of data availability and complexity. For example, consider a company that is interested in promoting education, specifically, improving literacy rates, through improvements in the supply chain. Literacy rate data would need to be identified, and the spatial specificity of this data would need to be considered. Additionally, the impact pathway between suppliers and change in social indicators is difficult to discern. These concerns are not limited to evaluating social sustainability; environmental sustainability faces similar difficulties. One of the approaches that has had some success in characterizing the broad environmental impact of a company or industry sector is input–output modeling.

Leontief [48] used an input–output representation to describe the monetary flows to/from industrial sectors in response to incremental changes in the demands on an economy. Input–output models have been established for economies at a variety of spatial scales (e.g., national, regional, and local) to understand the impact on the participating industrial sectors. Recently, the methodology has been used to predict the environmental effects (e.g., CO_2 emissions, effluent discharges, and solid waste outputs) associated with a change in demands [49]. Duchin [50] has examined the impacts of structural changes on input–output models, for example, impacts of less polluting techniques for generating energy.

Both Hutchins and Sutherland [51] and Norris, [17] have explored using input–output modeling to characterize the effects of changes in economic activity on social indicators. For example, imagine that a company is considering changing the supplier that provides a certain component. In this era of global outsourcing, it may be that the original supplier is within one country, and the potential new supplier is from a different country. To demonstrate the effect of such a change on social performance, consider the following relationship:

$$\Delta S_k = [f_k(M_i + \Delta M) - f_k(M_i)] + [f_k(M_j - \Delta M) - f_k(M_j)] \quad (1)$$

where f_k is a function that maps the monetary inflows of the ith country into the kth indicator of social performance, M_i is the base economic inflow into the ith country, and ΔM is the change in economic flow. As is evident, the change in the kth social performance indicator, ΔS_k, is the difference between the function

evaluated for a positive monetary increment for the *i*th country (new supplier) and the function evaluated for a monetary decrement for the *j*th country. Eq. (1) provides a relatively simple relation between a single input and a single output, but of course, this relation may be extended to consider more complex relationships among the inputs and outputs. The form of the equation is not as important as the purpose, which is to demonstrate that the selection of a supply chain partner could have a detectable impact and affect positive social change.

3.2. Example of input–output modeling of social impacts

To employ the relationship presented in Eq. (1), the first step is to establish a model that relates a social indicator to the economic flow. Fig. 5 displays the infant mortality as a function of gross domestic product (GDP) per capita, as reported in the UN's Human Development Report 2005. The vast majority of the 176 countries included in the data set are UN members and the data is almost entirely for 2003 – exceptions are noted within the report. It should also be noted the GDP is given in purchasing power parity (PPP) in United States currency ($U.S.). This approximates the exchange rate required to equalize the purchasing power of different currencies, given the cost of living for the countries under consideration.

Based on the illustrated data, the following model was established to characterize the infant mortality indicator:

$$S = 51,698(M)^{-0.898}, \quad (2)$$

where S is the infant mortality in deaths per 1000 live births and M is the GDP per capita. The "fit" of the equation, or R^2, is 0.7602. Of course, alternative forms for Eq. (2) may be created and further analysis is possible using other sources, including the regional and national level development reports published by the United Nations.

With Eq. (2) established, it may now be used in concert with Eq. (1) to predict the effects of a change in the supply chain. As an example, consider a situation where a company has a U.S. supplier that provides $100 million worth of components. It is desired to understand the social impact if a supplier from Mexico is used as an alternative. The populations for the U.S. and Mexico are 292.6 and 104.3 million and the corresponding GDPs per capita, M_j and M_i, are $37,562 and $9,168, respectively [52]. The birthrates (per 1000 people) for the two countries were 14.14 and 21.01 in 2005 [53]. This data was used to estimate the total number of births in 2003 – 4.137 and 2.191 million births in the U.S. and Mexico.

Using Eq. (2), the initial infant mortality rates predicted for the U.S. and Mexico are 4.030 and 14.30, and the total number of infant deaths would be 16,675 and 31,337. For the situation described above, the change in the economic flows for the U.S. and Mexico translates into new predicted infant mortality rates of 4.030 and 14.29. The U.S. infant mortality rate remains virtually unchanged because a loss of $100 million reflects only a 0.0009% change in GDP. In summary, the change in suppliers, and the resulting changes in GDP, will hypothetically result in an overall reduction of three infant deaths.

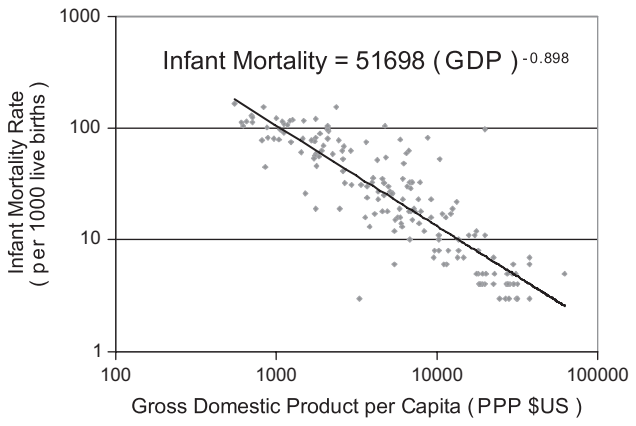

Fig. 5. Infant mortality vs. GDP per capita, 2003 (national data as reported in [52]).

4. Measuring social sustainability across the supply chain

Section 3.2 explored the selection of a supplier based on the effect of economic activity on national level measures of social sustainability. It suggested that global outsourcing decisions could be made to produce a net benefit in terms of social sustainability. There are several limitations of the work that was presented in Section 3.2. First, the technique enables national level comparisons; however it does not incorporate local or regional differences within a country and would not be useful in selecting from a pool of potential suppliers within one country. Additionally, although it is often necessary to make simplifying assumptions when making decisions, assuming an equal impact on social measures due to purchasing components made in Mexico City or a rural Mexican village may undermine efforts to improve social performance. Norris [17] provides significant discussion on the uncertainty associated with the use of national-average impacts. Another inadequacy involves the relationship between GDP and social sustainability indicators. While the model for infant mortality had a relatively good fit, attempts by the authors to model adult literacy as a function of GDP for data from 1997 to 2003 were much more difficult. For example, changes in GDP within a country from year to year frequently did not correspond to the expected changes in adult literacy. This may be due to a time delay between an increase in monetary flows and the improved infrastructure required to improve social conditions or a more complex relationship between adult literacy and key independent variables. Finally while the work in Section 3.2 provides a direct link between corporate actions and national indicators, as is evident, a single corporate decision may have a very small impact on national indicators. The effect of any single decision may be indiscernible relative to other factors that are changing, and as a result the use of indicators may be abandoned.

Building upon the work described previously, Section 4.1 contains an examination of several measures that a company may use to characterize its social sustainability. Then, a technique is introduced for characterizing the social impacts of a supply chain using the concept of a value-weighted social sustainability measure. Finally, an illustrative example is presented to demonstrate the applicability of this technique.

4.1. Measures of social sustainability for supply chain decision-making

As shown previously in Table 1, The U.N. Division for Sustainable Development [32] has proposed a number of themes and sub-themes to categorize a variety of social indicators. As is evident from the framework of the table, the indicators that are displayed cover a range of themes that could be used to describe the social "performance" of a nation or region. A cursory examination of the indicators/themes suggests that they are dependent on the form of government, government policies, cultural norms and expectations, social organizations, and business/economic activity. For a U.S.-based company interested in improving its social sustainability performance, it is clear that some of the indicators are influenced largely by entities outside of their control. For example, security, sanitation, drinking water, and education are provided by the government and paid for via taxes. Tax rates

and government-sponsored services, including benefits offered by public-sector institutions, vary around the world, with services generally proportional to tax rates. One might argue that higher tax rates would tend to promote higher levels of social sustainability; however, higher tax rates could dampen economic growth, ultimately leading to less tax revenues and less money available for social services. The topic of tax policy for sustainability optimization lies outside the scope of this paper.

Of course, the philanthropic activities of a corporation could greatly supplement government efforts to provide social services. Positive interactions between an organization and stakeholders improve how an organization is perceived, and ultimately affect the esteem and self-actualization of society. Many of the indicators/themes are dependent on the economic resources available to a family (e.g., poverty, nutritional status, healthcare and life expectancy, and living conditions) and, therefore, may be linked to corporate actions. A U.S.-based corporation may be evaluated based on the average wage paid to an employee relative to the cost of living in that region, wage equity, gender and minority wage equity, healthcare benefits, philanthropic activities, educational initiatives, and on the job safety of the workforce.

Businesses have taken various approaches to address the indicators described previously and have interpreted them in a variety of ways. To begin operationalizing social sustainability, a few representative indicators from the set will now be selected and precisely defined. The indicators that have been selected are not meant to exhaustively describe the social performance of a company, but rather serve as an example of the indicators that could be established. While meant as examples, these trial indicators may nevertheless be constructed from public (and often audited) information within Annual Reports, Sustainability Reports, Social Responsibility Reports, and citizenship initiatives. The following indicators are proposed:

- Labor equity – it is desired to establish some measure that describes the distribution of employee compensation within an organization. In principle, it would be desirable to base this measure on the wages for all the employees within an organization. For simplicity, in this case, it is proposed to use the ratio of the average hourly labor cost (including benefits and taxes) to the total compensation package (converted to an hourly measure) for the company's highest paid employee (often the Chief Executive Officer or CEO). The closer this ratio is to one, the greater the compensation equity within the company.
- Healthcare – a metric is needed to characterize a corporation's role in providing/supporting the healthcare of its employees and their families. This is especially true for companies operating in the U.S., where healthcare is not exclusively funded by the government – rather it is largely paid for by individuals and corporations. The specific measure that is proposed is the ratio of company paid healthcare expenses per employee to the market capitalization per employee. With respect to this measure, some discussion is in order. First, one might question the use of market capitalization as opposed to company revenue or profit in the denominator of the ratio. Differences among industry types tend to distort the perceived size of a company when revenue or profit is used to judge size, while market capitalization is the standard by which company size is determined. One might also question the advisability of using healthcare expenses per employee in the numerator in the ratio; certainly, a company that does not promote healthy employee lifestyles may need to absorb medical costs associated with heart surgeries, transplants, etc. A better measure might be health maintenance (or wellness) expenses per employee. Unfortunately, this expense is not readily available from most public information and is often aggregated with other healthcare-related expenses.
- Safety – to describe the safety of the workplace within an organization, an indicator is needed that increases as the social sustainability improves. Thus, lost hours due to injuries would not be acceptable for the purpose here. The ratio of average days not injured to the total days worked (per employee) was selected for this indicator.
- Philanthropy – a company plays important financial roles within a community and to greater society, which do not relate to its core functions as a business, e.g., building museums, funding performances and art shows, and providing fellowships to graduate students. We propose to describe a corporation's philanthropic commitment via the ratio of charitable contributions to market capitalization.

The four proposed indicators are quantifiable and the required information is generally available from audited corporate reports. Each indicator has been constructed so that as it increases, more social sustainability is achieved. These social indicators can be effectively utilized in decision-making related to supply chains. It is recognized that these four indicators do not completely cover all dimensions of social sustainability. However, they do address a spectrum of human and social needs, from basic to higher order, and therefore they represent a starting point to evaluate the social sustainability of supply chains.

To illustrate how these four indicators may be calculated, consider the public information available for the Ford Motor Company in the 2004 Annual Report to Shareholders [54], the Ford Sustainability Report [55] and Forbes [56,57]. From these sources the following is known for 2004:

- The average hourly labor cost (includes earnings and benefits) is $62.90/hour.
- The total compensation for Ford's CEO, William Clay Ford, was $181,700.
- The total money spent on current and non-current (automotive sector) employee benefits was $1,990,000,000 and $5,010,000,000, respectively.
- There was an average of 324,864 total employees and 276,029 automotive sector employees.
- The average number of days missed per 200,000 hours worked, due to a work-related injury, for 100 employees was 23.5.
- Ford and the Ford Motor Company Fund contributed $111,000,000 to charity.
- Ford's market capitalization was $25,000,000,000.

Assuming a 2000 hour work year per employee, Ford's labor equity ratio was 0.692. The average corporate healthcare expense per automotive sector employee was assumed to be equal to that of all employees, leading to a healthcare ratio of 0.33. The safety ratio and the philanthropy ratio were 0.999 (assumes 250 workdays per year per employee) and 0.0044, respectively. Having established these indicators, it is now possible to begin evaluating the social sustainability of a supply chain.

4.2. Evaluating the social sustainability of a supply chain

With a set of indicators proposed that could be used to characterize the social sustainability of a corporation, attention now shifts to evaluating a supply chain. As a first step, let us consider a company that stands at the start of a supply chain (see Fig. 6). The specific values of social performance for the company of interest are s_j, for $j = 1,\ldots,n$ where n is the number of indicators of performance. An overall measure of the social sustainability can be constructed by summing the weighted individual indicators as shown in Eq. (3):

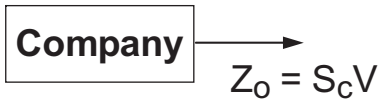

Fig. 6. Value-weighted social sustainability of a company.

$$S_c = \sum_{j=1}^{n} w_j s_j. \tag{3}$$

Selecting meaningful weights, w_j, for the social performance indicators may be challenging and the weights selected could vary from decision-maker to decision-maker. Methodologies are available to aggregate the differences in viewpoints among individuals such as the pair-wise comparison approach. However, while these methods are able to accommodate a diversity of opinions and value judgments, the resulting "averaged" weights may still be subjected to criticism or political opposition. Fundamentally, it is probably advantageous to work with a variety of decision-makers and experts to obtain an agreed upon rating system or importance of intensity factors [58]

The weighted overall measure of social sustainability, S_c, may be of interest all on its own. Certainly, it could be used to gauge the social sustainability of an entire corporation. In the case of a supply chain, however, the creation of a specific product is of interest and therefore concentration must center on the role of the corporation in creating the material or component of interest. To do this, we may determine a new measure that combines the social performance and the value of the material/component that is produced by the corporation:

$$Z_o = S_cV, \tag{4}$$

where it may be noted that V is the value of the specific output (material, product, or service) of interest being produced by the company, and Z_o is the value-weighted social sustainability measure.

Fig. 7 illustrates a situation where a company purchases material or components from another organization and then performs processes that contribute additional value to an output component or product. The value-weighted social sustainability measure for the supplier is termed Z_i, where $Z_i = S_iC_i$. The index i is used to handle situations where there are multiple suppliers. Note that relative to Eq. (4) above, value (V) has been replaced with cost (C_i) since the cost paid to purchase the material/component from the supplier represents the value of the item to the company. As is evident from the figure, the value-weighted social sustainability for the company includes the social impact of its suppliers and the social impact of the company itself and is given mathematically by Eq. (5):

$$Z_o = Z_i + S_cV, \tag{5a}$$

or for multiple suppliers as

$$Z_o = \sum_{i=1}^{k} Z_i + S_cV, \tag{5b}$$

where k is the number of suppliers.

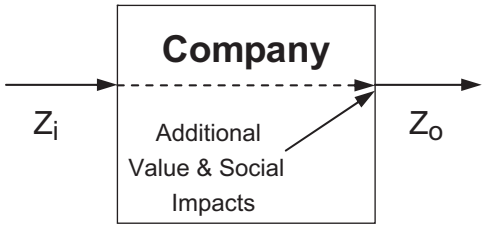

Fig. 7. Value-weighted social sustainability of a company within a supply chain.

All the relations are now in place to evaluate the social sustainability of a supply chain, and a brief example will be presented next to illustrate the use of the equations. Before doing this, however, let us consider again Fig. 6 and Eq. (4) that were used to describe a company at the start of a supply chain. In fact, it is virtually impossible to identify a company that has absolutely no suppliers. Corporations that are often placed at the start of supply chains, such as materials extraction and oil companies, purchase equipment from suppliers, and the costs of this equipment should be allocated to each product or unit of material that is created. Furthermore, all companies use some sort of labor and, in principle, the cost and social impact of these individuals should be incorporated into the value-weighted measure of social performance.

4.3. Example evaluating the social sustainability of a supply chain

Consider a hypothetical supply chain such as that illustrated in Fig. 8. Company A is seeking to improve its social sustainability performance. It has three direct suppliers, B1, C, and D. Company D has two suppliers E and F. It would be possible for Company A to replace supplier B1 with alternative suppliers B2 or B3, with no change in cost. The values for the individual social sustainability indicators for each supplier are given in Table 2. The management team at Company A has decided on the indicator weights shown in the table. These weights reflect the relatively larger importance the company places on labor equity and injury prevention compared to healthcare and philanthropy. The total social sustainability measures are the elements displayed in the bottom row of the table and were calculated using these weights and Eq. (3). When combined with the selected weights, the indicators for labor equity and injury prevention contribute a significantly larger proportion to the social sustainability measures than the indicators for healthcare and philanthropy. In this case, the distribution system was not considered; however, the companies involved in transport could easily be incorporated.

As can be seen in Table 2, Company B3's measure of social sustainability is significantly higher than that of Company B1 or B2. Therefore, in order to improve its overall social performance, Company A would elect to purchase from Company B3 opposed to B1. After making this supplier decision, Company A could then begin to explore the value-weighted impacts within its supply chain. First, the value-weighted social sustainability metric, Z_o, of Company D can be calculated using Eq. (5b) by combining the social sustainability metrics shown in Table 2 and the value/cost

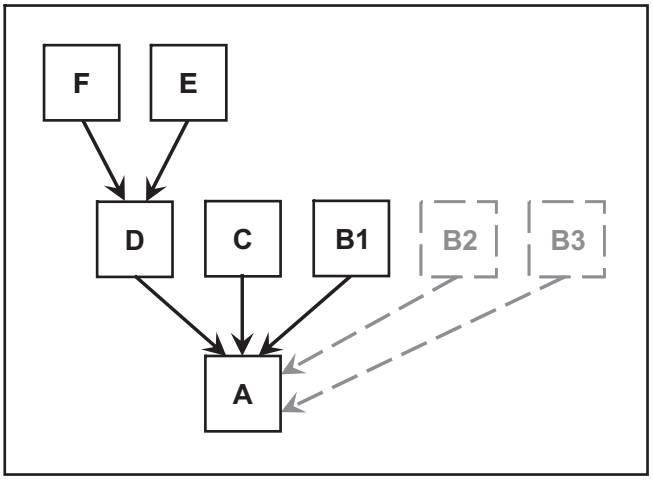

Fig. 8. Supply chain for company A.

Table 2
Social sustainability of Company A's supply chain

	Weight	Company							
		A	B1	B2	B3	C	D	E	F
Labor equity	0.60	0.637	0.249	0.182	0.526	0.086	0.317	0.067	0.493
Healthcare	0.75	0.048	0.036	0.064	0.028	0.072	0.06	0.024	0.048
Injury	0.25	0.999	0.998	0.999	0.999	0.999	0.999	0.963	0.998
Philanthropy	0.30	0.0006	0.0004	0.0013	0.0008	0.0005	0.0003	0.0017	0.0003
Social sustainability		0.668	0.426	0.407	0.587	0.356	0.485	0.299	0.581

contributions shown in Table 3. Then, the value-weighted social sustainability metrics for Companies B3 and C can be combined with Company D's to find the overall value-weighted social sustainability for the supply chain of Company A (see Table 4).

As Company A pursues improved social performance, it may want to identify both those companies in its supply chain with social sustainability measures that are relatively high and relatively low. For those suppliers with higher levels of social performance, Company A may want to strengthen its partnership with them. Potentially, these companies could serve as resources for guidance and information. Company A's social performance might also be improved by strengthening its partnerships with those suppliers that seem to be lagging. Company A could encourage suppliers with low indicators of social sustainability to improve through a variety of initiatives, such as training and financial incentives. Alternatively, Company A could replace low performing suppliers with more socially conscious companies.

As previously discussed, the call for sustainability requires businesses to consider environmental, economic, and social impacts throughout the life cycle of their products and services. Therefore, Company A may also consider the role of its suppliers in creating the item of interest by evaluating their percent contribution to the overall value-weighted performance (as shown in Table 4). This provides Company A with a value-weighted assessment of the social measures of the businesses within its supply chain.

5. Summary and conclusions

The concept of sustainability emphasizes the interrelationships among ecological, social, and economic systems. Until recently, efforts to characterize the social dimension of sustainability have largely been held in abeyance. The need for sustainable development and the push for corporate social responsibility are driving the establishment of decision-making tools directed at social impacts. In this paper, metrics and indicators of social sustainability and corporate social responsibility and their classification have been reviewed. A link was made between monetary activity and indicators of social sustainability on a national scale. Utilizing this relationship, it was demonstrated that an individual corporate decision can affect national measures of sustainability. Several indicators of corporate social sustainability were then proposed. These measures were subsequently employed in an example to demonstrate how decisions can be made to improve the social sustainability of a supply chain.

A number of new interpretations and concepts have been presented herein that contribute to the development of methods and tools for assessing the social dimension of sustainability. These include:

- A category hierarchy for a social LCA based upon the environmental LCA category hierarchy. The social category hierarchy provides insight into the mapping of corporate inputs and outputs into measures of social performance.
- A simple relationship and example that demonstrates that a corporate supplier decision can be linked to a social indicator (infant mortality) and that corporate actions can be used to effect positive social change.
- Several proposed measures of social sustainability for supply chain decision-making (labor equity, healthcare, safety, and philanthropy) that serve as a starting point to establish a comprehensive social footprint for a company.
- A technique to integrate a variety of measures of social performance to form a single social sustainability metric for a company.
- A method for combining the social sustainability metrics for companies to form a single measure of performance for a supply chain. This measure is based, in part, on the value that each supply chain partner contributes to the product of interest.

This work adds to a growing discussion on how to incorporate the social dimension of sustainability into business decision-making. To fully integrate social considerations into decision-making, much work remains to be completed. It is challenging to operationalize indicators of corporate social sustainability in decision-making related to supplier selection or supply chains – further efforts are needed. The relationship between business actions and social impacts must also be characterized. This includes identifying the critical variables, establishing the conditions under which the models are valid, and developing a process for weighting the indicators. Only through a better understanding of the linkages between business and society can we make progress on the path to sustainability.

Table 3
Value-weighted social sustainability of Company D and its suppliers

Company	Value/cost	Social sustainability		
		Raw measure	Value-weighted	Percent
D	8	0.485	3.880	0.486
E	4	0.299	1.198	0.150
F	5	0.581	2.907	0.364
Total	17	Total	7.985	

Table 4
Value-weighted social sustainability of Company A and its direct suppliers

Company	Value/cost	Social sustainability		
		Raw measure	Value-weighted	Percent
A	7	0.668	4.677	0.242
B3	9	0.587	5.279	0.273
C	4	0.356	1.422	0.073
D	17		7.985	0.412
Total	37	Total	19.363	

Acknowledgements

The authors gratefully acknowledge support from Michigan Technological University's Sustainable Futures Institute and the Sustainable Futures Integrative Graduate Education and Research Traineeship (IGERT) project funded by the National Science Foundation (Grant No. DGE 0333401).

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