ESTIMATING INJURIOUS IMPACT IN CONSTRUCTION LIFE CYCLE ASSESSMENTS: A PROSPECTIVE STUDY

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ABSTRACT

This paper is the result of a desire to include social factors alongside environmental and economic considerations in Life Cycle Assessment studies for the construction sector. We describe a specific search for a method to include injurious impact for construction Life Cycle Assessment studies, by evaluating a range of methods and data sources. A simple case study using selected Accident Compensation Corporation information illustrates that data relating to injury could provide a compelling evidence to cause changes in construction supply chains, and could provide an economic motive to pursue further research in this area. The paper concludes that limitations notwithstanding, the suggested approach could be useful as a fast and cheap high level tool that can accelerate the discussions and research agenda that will bring about the inclusion of social metrics in construction sector supply chain management and declarations.

KEYWORDS: Construction, Injury, Life Cycle Assessment.

INTRODUCTION

Consumers are able to confer their expectations over supply chains through purchasing power. In particular the emerging global demographic entitled 'lifestyles of health and sustainability' (i.e. LOHAS) wields particular power and influence in international and domestic markets (Chang, 2007). Consequently in recent years supply chain declarations that relate environmental performance have become more commonplace. And major retailers such as TESCO and WalMart in the US are moving towards a scenario where the reporting of supply chain performance is mandatory.

There are several international standards that provide methodological guidance for supply chain performance reporting e.g. World Resources Institute and the World Business Council for Sustainable Development's 'Product Life Cycle Accounting and Reporting standard' or the ISO14040:2006 'Standards and framework for Life Cycle Assessment'. However, to date, the majority of the methodological advances have been focused on environmental performance. Whilst there are several interpretations of what constitutes sustainability (Moore, 2012; Al-Waer, Sibley & Lewis, 2008; Holden, 2011); it is accepted that sustainability is not just environmental performance. Indeed the society the environment serves is important, as too the economy that is embedded in that society. Thus most interpretations of sustainability involve; the environment, the economy and social factors. However, recently the development of social metrics in Life Cycle Assessment has not mirrored the development of environmental and economic performance.

Life Cycle Assessment is a standardised scientific method for systematic analysis of any kind of flows (e.g. mass and energy) associated with the life cycle of a specified product or with technological or service or manufacturing process systems (Baumann & Tillman, 2004). According to the ISO 14040:2006 and 14044:2006 standards, a Life Cycle Assessment study consists of four phases: (1) goal and scope; (2) life cycle inventory (LCI); (3) Life Cycle Impact Assessment (LCIA); and (4) interpretation. The goal and scope stage outlines among others the rationale of the study, anticipated use of the results of the study, boundary conditions, data requirements and the assumptions to analyse the product system under consideration. The goal of the study is based upon the specific question that needs to be answered, the target audience, stakeholders involved and the intended application. The scope of the study defines the systems boundary in terms of technological, geographical, and temporal coverage of the study, attributes of the product system, and level of detail and complexity addressed by the study.

The LCI stage qualitatively and quantitatively documents the materials and energy used (i.e. input) as well as the products and by-products generated and the environmental releases to the environmental compartments and the wastes streams (i.e. output) for the product system being studied. The LCI data can be used on its own to: understand total emissions, wastes and resource use associated with the material or product being studied; to improve production or product performance; or it can be further analysed and interpreted to provide insights into the potential impacts from the system. This is done by synthesising the chemical emissions or resource use to a particular impact via the use of a characterisation factor. Thus a characterisation factor is a numerical description of the impact of the chemical emission or resource use. Consequently a disparate LCI can be brought together to a more digestible format that can then be analysed.

Work has been going on internationally for the last decade to quantify social impacts in parallel with environmental impacts using the life cycle assessment approach (Baumann & Tillman, 2004; Dreyer, Hauschild, & Schierbeck, 2006; Benoît & Vickery-Niederman, 2010), but theoretical studies on measuring social aspects of sustainability have heavily outweighed industry-based studies in the literature (Thatcher, 2012). In 2009 an attempt was made to define a baseline for Social Life Cycle Assessment through the publication of 'Guidelines for Social Life Cycle Assessment of Products' by a taskforce under the UNEP-SETAC Life Cycle Initiative (Benoit & Mazijn, 2009). This programme had multiple aims, but the most important one was '*to convert the current environmental tool Life Cycle Assessment into a triple-bottom-line sustainable development tool*'. The discourse around the International Labour Organisation's Decent Work initiative with its emphasis on health and safety has also been influential in identifying categories within the Social Life Cycle Assessment. There is still however, insufficient or clear agreement on what social impact categories to include and how to measure them (Jørgensen, Le Bocq, Nazarkina & Hauschild 2008); One of the main reasons for this slow progress is the fact that when undertaking studies on Social Life Cycle Assessment, it is necessary to incorporate a large amount of qualitative data, since numeric information will be less capable of addressing the issues at hand (Dreyer *et al*, 2006). In addition, data may often have to be collected *in-situ* since databases for specific social and socio-economic impacts are scarce and often incomplete. Further, unlike environmental conditions there is no agreed pristine state for societies that can be used as a benchmark. We can now generally measure how far the actions of a company in growing and harvesting a particular forest have altered the land from its native state. To do this we have to be able to describe what pristine looks like, and normally we can, by comparison to controls. But we don't have the same understanding or systems of measurement to similarly gauge the impact on individuals, families and communities of plantation forestry. We do not know what ideal state that community would look like, and even with a great deal of insightfully facilitated participatory development work they probably could not express a collectively agreed vision either. There are as many aspirational states as there are people, and so at one level the task of establishing baselines from which to gauge impact could be seen as impossible. However, if one accepts as a universally agreed vision, the human desire to constantly improve our conditions and those of our children in ways we have reasons to value, then we can start to measure other things that are agreed collectively to be necessary to progress (Sen, 1999). In short, more research is required before social impacts can be meaningfully quantified for supply chains servicing important sectors such as the construction sector.

This study is part of a prolonged effort over the last few years amongst the authors to progress discussions on possible approaches, and sources of data, for Social Life Cycle Assessment studies in New Zealand. Subsequently, this specific exercise was a search for characterisation factors for a health and safety social metric that relates to injurious impact. The main objectives being to: evaluate the potential sources of data, to identify injury hotspots in the use of timber in residential constructions presented by this method, and to highlight future research objectives.

RELEVANT INITIATIVES AND SOURCES OF SOCIAL IMPACT DATA

The following sections detail a range of initiatives that fit with the drive behind Social Life Cycle Assessment and may provide data or information that can help the development of Social Life Cycle Assessment metrics.

International Labour Organisation's Decent Work Initiative

Arguably, the most realistic and pragmatic approach to develop data suggested in the extant literature is from the International Labour Organisation's Decent Work initiative. The principle would be to adopt, as absolute minimums, the fundamental principles of the International Labour Organisation Decent Work initiative, and to then supplement these with locally derived measures that reflect the culture, aspirations and resources of the region or industry (Dreyer, 2010). Decent Work covers the absence of child labour, forced labour and discrimination, and allowing freedom of association including the right to organise collective bargaining. These are also widely referred to as the fundamental labour rights and are in theory covered adequately by New Zealand law. The absence of prosecution should be evidence that a New Zealand company is meeting these basic criteria (Seadon, Moore & McDevitt, 2010).

That will not always be the case of course, especially where industries draw upon a large body of people employed under non-standard conditions; for example undocumented workers, and poorly regulated on-hire staff. It has been suggested in the literature that occupational health and safety in developing countries has not been significantly enhanced by corporate social responsibility schemes (Pearse, 2010). And the question could similarly be raised as to whether Social Life Cycle Assessment initiatives intended to aid broader human development efforts could, through unintended secondary impacts, have the opposite effect. For example, if significant in-company studies are needed then the burden of cost and administration to undertake such rigorous studies will be disproportionately on the micro, small or medium-sized businesses (Seadon *et al*, 2010). Indeed, there is already real concern amongst smaller companies that the larger ones will use certification schemes or mandatory reporting requirements relating to environmental and, to a lesser extent, social impacts to improve their competitive position. Moreover, within the New Zealand housing sector there are as many as 50,000 small firms employing an average of just three staff each (DBH, 2009) and any additional costs need to be clearly justified and seen as equitably shared across the industry.

Locally agreed social impact targets

Desirable locally agreed social impact categories are ones that are not only seen as legitimate and meaningful but can also be affordably and accurately measured. At a high level, at least, it is useful to have measures that are already routinely collected for other purposes (e.g. legal requirement) and are therefore obtainable by the researcher with reasonable ease and minimal cost. To provide clear cost benefit analysis, it is also helpful if the locally collectively agreed social goals are ones that companies are already 'taxed' against. Examples of locally agreed targets in New Zealand may well therefore include: improving health and safety performance beyond legal minimum national standards. Or improved employment opportunities provided by the company to comply with local Human Capability Framework characteristics. By this we mean fitting the jobs to the people so that through the skills, knowledge and attitudes people possess, they can take advantage of the labour market and other opportunities available to them (Tipples, 2004). A simple example would be the redesigning of a task that has a very hard manual component to it by reducing the weight of the loads so that a wider pool of people would then be able to undertake the task. This not only helps the potential employees but also provides the company with a wider choice of applicants thereby improving the chances of a good match between employee and job.

New Zealand National Health and Safety Performance data

Table 1 shows a review of data sources that can be used to investigate areas with potential for improvement of social impact. The table starts at the highest level of data collection and then narrows to focus on the intervention design for particular enterprises and tasks.

Table 1 - Levels of impact study related to health and safety management of high risk tasks

Sources	Description	Strengths & Weaknesses
Accident Compensation Corporation Levy Settings	Based on the Australian and New Zealand Standard Industrial Classifications, the levies are set by Classification Units. High risk jobs with high claims pay more and so it is an easy way to see if a company has designed its operations to include high risk tasks. Each occupational group has a classification rating which determines what levy rate per $100 they have to pay	It is simple and easily accessible as a resource for high level studies. It is contentious when used to develop interventions. Not all people doing higher risk tasks make more claims. Aggregation of tasks leads to anomalies at detail level.
Accident Compensation Corporation claim narrative entries	Interrogation of the narrative entries of the individual Accident Compensation Corporation claims by sector or company. The narrative describes what happened and so provides some context and possibly ability to identify subtasks	A strength is that high risk subtasks and important details about context can be positively identified in some cases. Weaknesses include: Inconsistency, Inaccuracy in entry or coding, Under-reporting.
Workplace Accident Register analysis	Workplace accident registers are required under law, and have been used as a source of in-depth data in previous studies (Moore, Tappin & Vitalis 2004). Line by line analysis provides better data than Accident Compensation Corporation narrative generally	High quality data and causal factors may be more accurate than in Accident Compensation Corporation claims data due to motivations for bias. Underreporting of gradual onset problems especially. Costly in time and resources.
In-depth workplace studies	Once high risk tasks and subtasks have been identified through the above measures, detailed multi-method investigations follow of these elements in the work systems where warranted	Provide sufficient detail to confidently develop interventions and implementation plans. Most expensive and require most highly qualified expertise.

Table 2 shows an example of how levy settings, and exposure to these occupational task groups (as expressed by pay received for hours worked) may be used to identify areas that warrant further attention, if improvements to injury prevention as a social impact are sought. The materials data for the exemplar house is from Willson (2002) and the life cycle inventory data is mostly from Ecoinvent and similar life cycle inventory databases (PE International, 2009; Frischknecht *et al.* 2005). More specific information on the exemplar house data can be found in Love and Szalay (2007).

Table 2 shows clearly that the injurious hotspot, for the timber contribution to the exemplar house, occurs during the construction phase in the house life cycle. The calculated impact of construction is at least an order of magnitude greater than any other stage in the life cycle of the house. Another notable output is that the timber processing phase is significantly more injurious than the forestry production or house demolition phase.

Table 2 - Accident Compensation Corporation levy totals per process involving timber components in the exemplar house (Willson, 2002).

Process	Classification	Total Wages / Earnings related to this house	Accident Compensation Corporation levy rate[1] NZ$ per $100 gross earnings	Total Accident Compensation Corporation levy due to nearest NZ$
Growing	Forestry production[2]	245	4.17	10
	Transport[3]	48	2.63	1
Milling	Timber processing[4]	857	2.26	19
	Transport[7]	171	2.63	4
Building	Carpentry[5]	7670	2.67	205
	House construction	7670	2.55	196
Demolition[6]	Site preparation services	205	0.63	1

Notes to Table 2:

1. Levy calculated as a % of every $100 paid out in wages to employees or received as earnings by self employed.
2. Includes logging ($4.14) and forestry ($4.17). 12,284 kg of solid wood and wood products in the house. Assuming a 7 man crew producing 172 tonne a day, 50% yield at the mill, and an average pay of NZ$60k. Estimated generic figures from Scion Human Factors team. Allowance added for silviculture and pruning.
3. Transport assumes movement as 1/3 of a 40tonne load, for half a day with a sole driver earning NZ$70k a year. This is based on $22/hr but with a 70hr max week that is quite normal to work. Figures from TERNZ.
4. Assumes a mill producing full set of finished products. Mill output 100,000 tonnes a year with 165 staff on mean wage of NZ$42k. 606 tonnes per staff/yr, 2.5 tonnes per staff/day.
5. Labour costs for all timber related work totaled and halved into carpentry and house construction classifications – impossible to state which they would all come under.
6. Estimated 12% (based on weight) share of demolition and site clearing labour costs for a typical house of this construction not including specialist machinery operation for heavy elements masonry and steel.
7. Conservatively assumes everything arrives in a few well planned trips totaling one days worth of driving.

DISCUSSION

This review paper has highlighted some of the available data and limitations thereof, to including injurious metrics in conventional Life Cycle Assessment studies. Despite a broad acceptance of the role of social metrics to achieve sustainability the associated methodologies are nascent. This has caused inertia in integration of Social Life Cycle Assessment that is compounded by ambiguity about what to measure. Therefore identifying and reviewing data and methods is a crucial step in the transition to including social metrics and achieving sustainable consumption and production systems.

Given that the New Zealand residential construction industry has one of the highest injury rates and that it is a broad industry, we have concentrated on specific areas of concern, namely carpentry and timber product-related work on the building site itself. The rationale for this approach is that interventions can be targeted to reduce negative social impacts (injury and illness costs in this case). A possible intervention could be increasing pre-fabrication of the house construction so that more framing work and assembly is done off site – normally indoors under better controlled light industrial conditions. On site work of this type is rated at around $2.60, offsite (i.e. the 'Pre-fabricated wooden building manufacturing' category) it is rated at $1.93 using the Accident Compensation Corporation work levy rates (ACC, 2012). Though, it should be noted that the choice and manipulation of data will undoubtedly influence the output and findings. Also this is a simplified example to illustrate the possibilities, and there is clearly a need for further research. In particular there is a need to develop a robust methodology that enables one to further analyse the impacts by job-task and material exposure.

Future research should also include the building methods of other countries in which off-site prefabrication is the norm. The purpose of this expanded research would be to examine the wider social effects of introducing a more industrialised approach to a sector heavily populated by small businesses and sole traders. Closer scrutiny of the health implications of working different timber types, specifications and treatments is also warranted. Moreover, other health issues common in this sector, such as musculoskeletal disease, emerge slowly as a result of multiple exposures to sets of risk factors, yet these chronic health issues often remain underrepresented in the official figures. The direct costs paid by Accident Compensation Corporation are small in comparison to estimates of indirect costs related to an injury, which are borne mostly by the individual and their family. Further, there is anecdotal evidence to suggest that musculoskeletal issues and other health problems that emerge slowly as a result of multiple exposures to sets of multiple risk factors are common in this sector. However they remain underrepresented in official figures too. Indeed proving causality is a significant limitation of this method and thus warrants further consideration and development.

There are a number of general issues that need to be acknowledged when using government data, for injury surveillance or workers' compensation data. The Accident Compensation Corporation together with Statistics New Zealand mainly generates claims data for the purposes of administering claims and managing rehabilitation resources. Another complication is the fact that injury definitions and categories within the government agencies' databases have changed over time. Accident Compensation Corporation data is also not sensitive enough to provide generic data for housing workers drawn from the non-standard New Zealand work sector including on-hire staff who may move between sectors. The levy rates may therefore be based on an underestimate of the incidence and/or severity of claims relating to building site work.

Using nationally collected data means that we can apply consistent principles associated with the data collection to the disparate supply chains that service a residential construction project thus enabling parity between sectors. The relationship between supply chains for complex constructions may be mirrored in other countries therefore the relationship found in New Zealand could be used a conduit for regions where there is a paucity or absence of suitable data. The economic components of the Accident Compensation Corporation data means that data collection is taken seriously, it is auditable and the impacts captured by financial costing are relatively holistic.

To progress Social Life Cycle Assessment as a discipline, it may well be necessary to distinguish more closely the various elements of society impacted. Vanclay (2002) for example, identifies seven categories/strata of society. More radically it may also be necessary, or advantageous, to consider measuring social impact as an indirect consequence of environmental impacts; where decrement in the biophysical environment reduces its functionality as a provider of human needs or wants (Slootweg, Vanclay & van Schooten, 2001). Indeed the relationship between the social, economic and environmental impacts of the supply chains that are used in the construction sector are to date under-investigated. Therefore a substantial amount of research and development will be necessary to achieve sustainability in current construction supply chains.

CONCLUSIONS

There are clearly difficulties when undertaking empirical studies involving Social Life Cycle Assessment. Not only are there conceptual ambiguities but there are also issues around what specific impact categories to include, and how to measure them. The quantitative data needed for incorporation into Life Cycle Assessment studies is not abundantly produced by current research activities. This may be because current research is more focused on qualitative exercises aimed at building understanding and conceptualising nebulous problems.

There is a very high level suite of universally agreed social targets of relevance and these are generally measured. However, United Nations led interventions and other top-down international initiatives, have to be supplemented by sensitively selected and measured, local metrics. In the case of the New Zealand residential building sector, the general principle of freedom from occupational injury is represented in our health and safety legislation, and a crude but invaluable set of performance data are built annually by Accident Compensation Corporation. Levy rates provide a very high level indicator of risk by occupational group. Consequently the levy rates may be a suitable platform for a characterisation factor relating to injury in construction Life Cycle Assessment studies.

The findings of this study suggest that despite clear limitations, the sources of information we have investigated so far could be useful to the development of Social Life Cycle Assessment exercises to help identify hotspots and progress future research agenda. The research need to be refined through more cases studies across a range of sectors domestically and abroad. This is because without including a social element to the assessment of supply chains, true sustainability may be unachievable. Hence further work is warranted - it will have considerable merit - and the work presented in this paper may provide a solid platform for such research.

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