

Greening Procurement: A Research Agenda for Optimizing Mass-haul During Linear Infrastructure Construction

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Abstract

Infrastructure construction generates a significant amount of global economic activity. Much of infrastructure construction is government sponsored through a procurement process. Currently the ideals of sustainability are not embedded in these processes because methodologies to measure green house gas emissions produced *during* infrastructure construction are yet to be developed. Both government road and transport authorities and contractors require these tools. As a way forward, an agenda for preliminary research focusing on a special case is suggested. As mass-haul is known to produce high levels of greenhouse gas emissions it would make an excellent construction activity to explore. If it is possible to optimize the amount of handling and movement of soil, aggregates, and rock around projects, then it is possible that green house gas emissions could also be measured and optimized. Therefore a three-pronged research agenda is proposed, centered on mass-haul activity, in order to develop prototype methodologies and tools for green procurement processes that contribute to sustainability of the built environment.

Keywords

Construction procurement, Linear infrastructure, Optimizing mass-haul, Sustainability methodologies

1. Introduction

One of the most significant components in linear infrastructure projects (roads, railways, tunnels and pipelines) concerns the handling and movement of mass materials (soil, aggregates, rock) around the project. These diverse activities are called earthworks or mass-haul and can account for around 30% of the cost of the total project. However, if the physical effort and movement side-effects are taken into account, the environmental impact of these operations probably adds to the overall cost of a project.

The problem with the current situation is that earthworks operations are necessarily high consumers of energy, consuming millions of liters of petroleum products, and are consequently high contributors to the carbon-footprint of all linear infrastructure projects. Optimization of mass-haul operations has the potential, not only to reduce the cost of construction, but to contribute to environmental sustainability. This could be accomplished by significantly reducing the carbon-footprint for a total project based on both financial and non-financial factors of construction (Kenley *et al.*, 2000). However, at present the methodologies and tools to measure greenhouse production of mass-haul *during* infrastructure construction are missing. Thus, an overarching research agenda is required to develop methods, processes and criteria for planning, evaluating and monitoring the carbon-footprint of linear infrastructure construction mass-haul. The expected outcome of

such an agenda would be development of measures and methodology prototypes enabling a significant contribution to greening procurement processes for a sustainable built environment.

The balance of this paper will provide the rationale for an agenda to develop the measures and methodologies for mass-haul greenhouse gas emissions (GHGs). The sustainability perspective of construction of the built environment is outlined in section two. Section three focuses on the specifics of the carbon-footprint concept in the debates surrounding issues of environmental impact. Mass-haul research in relation to the problems of resource optimization and the production of greenhouse gases (GHGs) is the basis of section four. Section five outlines a three-pronged research agenda to develop prototype methodologies and tools to measure GHGs that could assist in greening procurement for linear infrastructure construction.

2. Sustainable Construction

Rapid economic growth over the last two centuries has provided a higher standard of living for many on the planet, but this progress has been accompanied with high levels of environmental degradation. Thus the exploitation of natural resources in relation to the built environment is a topic considered by a number of scholars (Vanegas, 2003) who consider issues of sustainability.

The sustainability debates have been a concern for non-economic factors, social and environmental wellbeing, that are affected by the construction process (Hill and Bowen, 1997). In an attempt to quantify the application of sustainability procedures, a review of the Annual Reports of publicly listed UK construction companies was undertaken. Meyer (2005) found little evidence of a concern with sustainability by these companies, of either the built or natural environments. Seven years later, Smyth (2010) found an insignificant shift in the number of projects and organizations taking into account the social aspects of environmental sustainability through co-operative and inter-disciplinary working practices in the UK construction industry.

It appears that sustainability as an accepted and under-lying perspective remains at a policy and theoretical level 20 years after the World Commission on Environment and Development (1987) articulated the issues. The problems associated with changing behaviors within complex systems (Yannis *et al.*, 2010) and long-lead times for the diffusion of new ideas (Walker and Hampson, 2003) provide rationales for the limited operational acceptance of sustainable construction. Although evidence of a limited shift could be assumed by the financial commitment from contractors, consultants and government agencies for sustainable construction research through the collaborations such as the Australian Sustainable Built Environment National Research Centre (SBEnc 2010).

3. Carbon-footprint

One of the major sustainability initiatives supported by governments has been the development of the concept of an ecological footprint. The concept was devised as a simple metaphor for a very complex issue. The idea is that a defined land mass can be assessed for sustainability. Various multi-factor measures have been developed for countries, regions, cities, communities, individual farms and single residences. These measurements are based on the question "Can the population within a defined geographic parameter be sustained by the production within that area?" However, both the number and the variety of factors for each specific situation calls into question the original general assumption (Kitzes *et al.*, 2009).

None-the-less, this starting point has resulted in a continuing exploration of the ideal of sustainability utilizing the footprint metaphor. Indeed, the growing research and literature in the area of ecological economics has expanded and modified many of the original calculations. For example, Lenzen and Murray (2001) discuss the effects of the built environment in the Australian context. They provide details of different types of land use, emphasizing linear infrastructure such as pipelines, road and rail. Clearly these necessary structures make possible land use for food production and recreation. This important distinction expands the original concept of carbon-footprint applied to food production to include all types of land use and increases

the factors to be considered in development of methodologies and measurements of GHGEs (Huang and Lo, 2011).

The energy sector now uses the carbon-footprint concept to frame discussions of both renewable and non-renewable sources (Gasparatos *et al.*, 2008). This accepted concept is utilized by energy producers and users as well as a variety of stakeholders along the industry supply chain. Transportation researchers have also found the footprint idea useful in discussion of fuel consumption and emissions (Amekudzi *et al.*, 2009). The production of excessive amounts of CO₂ and other GHGs by vehicles on the growing number of roads is a major concern for governments worldwide. However, most of the research to-date is concerned with vehicles that use the roads, not the vehicles that build the roads. The concept of a footprint is also appealing to built environment researchers concerning finished buildings, but not the carbon footprint created *during* construction (Ding, 2008).

4. Linear Infrastructure Construction Mass-haul

The methodologies to measure green house gas emissions produced *during* infrastructure construction are yet to be developed. This may be because of the complexity of projects. One means of simplifying this complexity would be to limit the current extensive number of variables by focusing on only one type of construction activity. By focusing on a special case, it is assumed that prototype methodologies and tools could be developed. One obvious type of activity is mass-haul because it is known to produce high levels of greenhouse gas emissions (Norgate and Haque, 2010). It would make sense to build on the productivity optimizing research by adding environmental factors as a step towards prototype development for reducing GHGEs.

A major part of the construction of linear infrastructure (roads, rail and tunnels) is the movement of materials such as topsoil, rock and clay. The collective term, mass-haul, is used to indicate the diversity of substances as well the variety of hauling and handling activities. A number of specific factors have been the focus of mass-haul research with a view to providing a formula for optimal productivity. Three common optimizing factors considered are geography (Moreb, 1996), machinery (Duffy, 1998) and planning (Askew *et al.*, 2002).

The development of simulation programs (Dawood and Castro, 2010; Smith, *et al.*, 2000) has provided researchers with the ability to investigate an expanded number of factors involved in the processes of mass-haul during the construction phase. For example, decision-making points, discrete-events and activities have all been researched (Holla and Schabowicz, 2010). Optimizing these factors is considered important in the development of intelligent construction systems (Kim and Russell, 2003). While research continues in automation technologies for optimizing productivity in mass-haul, the addition of factors related to sustainability are yet to be considered.

One of the major metrics for evaluating construction is environmental impact based on petrol consumption and CO₂ emissions (Sommer *et al.*, 2010). However, today little research has focused on reduction of mass-haul fuel consumption. It may be because specialist mass-haul vehicles are used in linear infrastructure construction optimization of fuel is considered intrinsic to machinery design (Duffy, 1998). Lack of data for fuel consumption may be one reason that mass-haul optimization has not been considered in the environmental sustainability research (Hendrickson and Horvath, 2000).

Currently environmental sustainability research on infrastructure design and operations a contractor's environmental performance score (EPS). The score is based on a limited number of factors: operational activities, site management, project management, environmental management technology and policy (Shen *et al.*, 2005). However, this overview of the construction process is too general to supply evidence of decreased GHGEs for a specific operational micro-process such as mass-haul.

5. A Three-Pronged Prototype Research Agenda

At present both road and transport authorities and contractors desire methodologies to assist them to minimize the carbon-footprint of mass-haul operations, but they do not have tools. Thus a research agenda to develop prototype methodologies to measure and monitor greenhouse gas emissions during linear infrastructure construction is necessary.

In the past government compliance requirements have proven to be a driver for change in the construction industry (Purchase and Dooley, 2010). E-procurement is becoming the industry standard (Eadie and Perera, 2010). Therefore it may be that the road and transport authority procurement requirements are one place to connect the concerns with sustainability, carbon-footprint, greenhouse gas emissions and optimizing mass-haul processes. Thus, a three-pronged prototype research agenda is suggested to support the development of a sustainable linear infrastructure construction procurement protocol.

5.1 Research Agenda for Developing a Methodology for Comparison of Bids

A methodology is required to compare project tender operations for meeting sustainability objectives through the mass-haul component of linear infrastructure projects. Three questions are at the centre of this methodology:

1. Are there currently methodologies available for comparison of local, country or international standards relating to procurement documentation?
2. Are there any research findings based on mass-haul processes during linear infrastructure that have led to measurement methodologies and tools that can be used as a benchmark for sustainability objectives?
3. Has 'green' procurement documentation been developed for micro or macro levels of construction sustainability?

5.2 Research Agenda for Developing an Assessment Methodology for Optimizing Mass-haul Carbon-footprint

Matar *et al.* (2008) provide a guide to the difficulties of identifying usable parameters for a sustainable construction index. The answers to four questions would provide the beginnings of a research stream:

1. Are there existing ICT applications that are able to measure mass-haul within linear infrastructure projects?
2. Is it possible to obtain data on petroleum product use for mass-haul operations?
3. Is it possible to optimize the mass-haul carbon-footprint on specific construction projects?
4. Are there currently methodologies available for comparison of local, country or international GHGE standards relating to mass-haul for linear infrastructure projects?

5.3 Research Agenda for Developing a Methodology for Monitoring Conformance with Bids

Compliance is one of the most critical factors for establishing improved environmental assessment of mass-haul operations. This requires both the monitoring of actual performance and control mechanisms (Kenley and Seppänen, 2010) to restore planned performance in the event of deviation (Navon and Shpatnitsky, 2005). Application of defined methodologies and tools could be based on answers to these five questions:

1. What methods would be effective and practical for on-site monitoring?
2. What industry benchmarks would be appropriate for measuring environmental and carbon impacts?
3. What management systems would be required for active control to ensure GHGEs levels did not deviate from project plans?
4. How can forecasting tools be incorporated into modeling the effects of mass-haul processes?
5. What would be the best format for effective reporting mechanisms?

6. Concluding Remarks

Past experience indicates that moving towards a problem solution is possible with a well defined research agenda. A research agenda pinpointing procurement processes is suggested to fill a noticeable gap between environmental research into carbon-footprint impact and research concerned with linear infrastructure construction efficiency.

It is possible that the problem of reducing the carbon-footprint may be achieved *during* the construction phase of linear infrastructure by exploring and redefining mass-haul fleet activities. Mass-haul operations, are known to have negative environmental impacts. However, clearly identified measurement methodologies and tools that will limit those impacts are yet to be developed. This three-pronged research agenda provides one blueprint for road and transport authority procurement requirements.

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