EXPLORING THE SUSTAINABILITY IMPACTS OF THE CONTEMPORARY SOUTH AFRICAN FREIGHT TRANSPORT SECTOR

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ABSTRACT

Despite being a significant driver of non-renewable resource consumption and other adverse sustainability impacts, freight transportation forms a vital component of the South African economy. This paper aims to illuminate and explore the overall sustainability impacts of the contemporary South African freight transport system through the proposal and implementation of an assessment scheme that is able to suitably capture and measure said impacts. The reason for gaining a better understanding of these impacts is twofold: firstly, apt and focused mitigation strategies can only be formulated once this information is understood and available and, secondly, this information can serve as a benchmark for future studies that aim to measure the success of mitigation interventions. At the core of the proposed assessment scheme lies the disaggregation of sustainability impacts into economic, social and environmental impacts, respectively. The scheme is applied to strategic level data, which is representative of current freight transport activities in South Africa, and spans five modes of freight transportation (road, rail, air, coastwise shipping and pipelines). Comparisons of overall sustainability impacts across modes are made. The findings suggest that road and rail transport are the weak links in the contemporary South African freight system. This can be attributed to the modes' high transport volumes and equally high infrastructure requirements.

1 INTRODUCTION

Freight transportation affects the lives of every South African on a daily basis. The sector is a fundamental component of the economy, serving as the connection between suppliers and their markets. It directly impacts the availability, accessibility and affordability of goods in an economy. The indirect impacts of freight transportation are, however, often neglected. Although the necessity for freight transportation is not under dispute, the question remains whether South Africans realise the true cost that they are paying for this service. In this paper, the authors attempt to expose the external costs of freight transportation in South Africa, with an aim to alert South Africans and decision makers to the opportunities and threats currently prevalent in the system. The information provided can be used in the development of apt and focused impact mitigation strategies and can serve as a benchmark for future studies that wish to measure the success of such strategies.

The paper develops with a discussion of the key elements comprising a freight system as they are defined in this study (section 2). Section 3 starts with a brief introduction to the "triple bottom line" construct found in sustainability literature, followed by an explanation of

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the methodology proposed to assess the impact of the freight system on each of these sustainability elements. The assessment scheme is then used to assess the sustainability impacts of the contemporary South African freight transport system in section 4. The paper concludes with some final remarks and recommendations in section 5.

2 UNDERSTANDING FREIGHT TRANSPORT

Freight transportation is the process of moving different types of goods (the transport load) from one point (the origin/producer) to another (the destination/consumer). To enable this movement, a mobile platform is needed on which the load can be placed and physically transported. This mobile platform needs to be connected to some form of propulsion system in order to move forward (the vehicle). The propulsion system, in turn, requires a connection to an energy source to power the movement, which implies the need for an energy supply network that ensures access to energy along the entire route. A qualified person (transport operator) is required to initiate, navigate and oversee the propulsion of the vehicle. It needs to be physically possible for the vehicle to safely move between the origin and the destination, hence the appropriate infrastructure has to be in place. Different transport modes and vehicle types place different infrastructure demands on connections between origin and destination pairs. Note that for pipeline transportation the infrastructure and the vehicle is one and the same. The entire transportation system is subject to rules and regulations enforced by the relevant governing authorities. Figure 1 is a schematic representation of the key elements comprising a freight transport system.

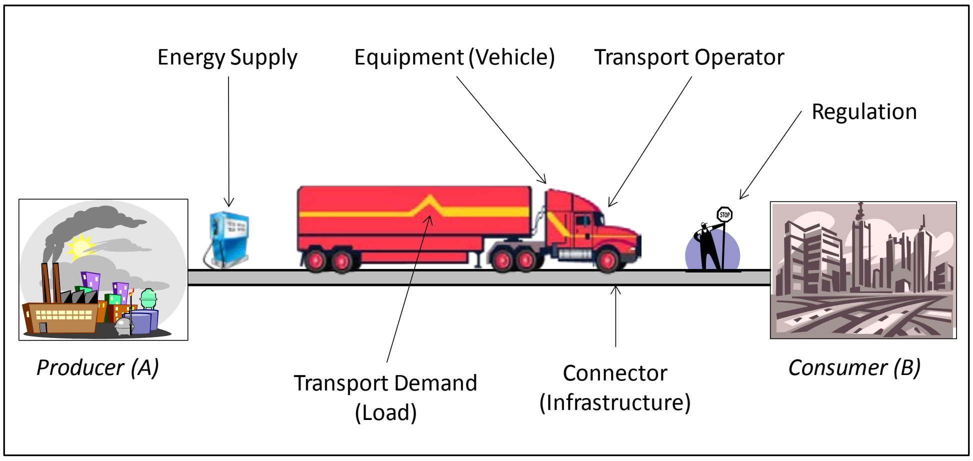

Figure 1 – Schematic representation of a freight transport system

The sustainability impacts generated by freight transportation can be classified into two distinct categories: first and second level impacts. First level impacts result from the physical transportation act and are, mainly, attributable to the propulsion of the vehicle. Second level impacts arise from the provision of all the elements required to enable transportation. It includes the impacts generated by the necessary energy supply, infrastructure supply, vehicle supply and maintenance operations. First and second level impacts are included in this study. It should be mentioned, though, that as this study is interested in the sustainability impacts generated by the *contemporary* freight transport system, impacts related to the provision of new infrastructure and new vehicles is excluded from the analysis. Only the impacts resulting from the upkeep of existing infrastructure and vehicles are included.

There are five modes used in the transportation of freight in South Africa. These include: road (accounting for approximately 60% of total tonne-kilometres), rail (around 30%), air freight (less than 1%), cabotage (less than 1%) and pipelines (around 7.5%). All five modes are included in this study.

Transport is powered by one of two energy sources in South Africa, namely electricity and liquid fuels. Electricity is primarily supplied from coal-based generation plants and is used in rail and pipeline operations. Liquid fuels, produced both from coal and crude oil feedstock, are supplied to the road, air and water transport modes in the form of diesel, jet fuel and bunker fuels, respectively. Both energy sources are included in this analysis.

3 METHODOLOGY FOR THE ESTIMATION OF SUSTAINABILITY IMPACTS

In 1987 the Brundtland Commission defined sustainable development as "development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" (UN World Commission on Environment and Development, 1987). Elkington (1997) later introduced the concept of the "triple bottom line" – the notion that economic activity can deliver financial, social and environmental benefits simultaneously. The vast majority of modern literature on sustainability management is based on a combination of these two theoretical constructs. In keeping with this trend, the authors have decided to measure the sustainability impact of the freight system based on its impact on the economy, society and the environment combined. Unfortunately, a standard assessment scheme that could be readily adopted in this study, did not exist. Richardson (2005) explains: "even with this agreement on the triple bottom line, virtually every individual and group that addresses transportation system sustainability develops a different set of variables that they consider to be the indicators of sustainability". As such, the authors have developed the assessment scheme used in this analysis.

The following insights were gleaned from a comprehensive literature review on the development of sustainability assessment models. Firstly, units of measurement need to be compatible over the "triple bottom line". The three "bottom lines" need to be linked and not isolated; hence feedback should be included in the model. It is advisable to avoid the monetisation of impacts as far as possible. Data availability and the objective of the study at hand are the two dominant issues impacting the range and selection of assessment criteria.

A review of South African studies on the topic of transportation and sustainability indicated that there is little information available on the scope of sustainability impacts generated by the South African transport system. Particularly few studies have been done on the freight system. Krynauw and Cameron (2003) found that, although the proposed South African transport key performance indicators could be used to measure the sustainability of the transport system from an operational and costing perspective, they could not reflect directly on other aspects of sustainability (such as the intensity and efficiency of energy use, the intensity of emissions of the road vehicle fleet and the environmental and health consequences of energy consumption, emissions production and road accidents). Zietsman et al. (2009) developed a tool to assess the sustainability of transport based on a set of 12 performance measures. The tool was specifically developed for a highway application and did not aim to link the performance measures to the "triple bottom line" definition of sustainability. Similarly, Jorgenson (2010) listed a number of transport externality costs which should form part of a sustainability assessment, but a framework for such an assessment was not developed. As a precursor to this study, Lane and

Vanderschuren (2010) evaluated the environmental impact of the South African freight transport system. Economic and social impact assessments were not included.

3.1 Overall sustainability impact estimation

Systems thinking forms the foundation of the sustainability assessment scheme used in this analysis. The fundamental construct of the methodology is to connect the first (transport activity related) and second (transport enabling element) level impacts to the components of the "triple bottom line". A bottom-up approach is taken, implying that data is collected at low levels of aggregation, which allows a multitude of aggregation possibilities in the results analysis.

Figure 2 schematically represents the methodology for the assessment of the overall impact of freight transportation on sustainability. This consists of cumulating the economic, social and environmental impacts generated. The impacts of each of the "bottom lines" are normalised before they are added together. It is important to bear in mind that the economic, social and environmental impacts all affect each other and that these interactions have been included in the assessment. Despite there being many arguments in favour of the application of a weighting system to reflect the relative importance of the three "bottom lines", it is not deemed justifiable to give preference to any element in this study and weights are, therefore, omitted. The assessment scheme described allows one to ultimately compare the relative contribution to each "bottom line" from every mode of freight transport. Regrettably though, the actual value calculated as the overall sustainability impact of freight transport in South Africa is only useful if it can be compared to a benchmark level (e.g. if this study were to be repeated in the future). Due to the aggregate nature of the assessment scheme, the actual values of the figures calculated have no distinct meaning.

Figure 2 – Overall sustainability impact assessment scheme

3.2 Economic impact estimation

Most countries aim for sustained economic growth. South Africa is no exception to this rule. Economic growth can be achieved in two ways (Saari, 2006). One way is through an increase in the total volume of inputs in an economy, given that the conversion efficiency from inputs to outputs remains constant. The second is an increase in this conversion efficiency (henceforth known as productivity). Evaluating the economic impact based on productivity theory is regarded as a highly appropriate assessment method in this study. The KLEMS multifactor productivity measurement model (see Equation 1), as described in OECD (2001), forms the backbone of the economic impact assessment. In the KLEMS model, productivity is measured as the ratio between outputs and combined production

inputs. In this study, output can be regarded as the volume of goods moved (measured in tonne-kilometres). All inputs are measured in terms of their South African Rand values.
The KLEMS model is represented by the following equation:

$$Multifactor\ Productivity = \frac{Output}{KLEMS} \qquad \text{(Eq. 1)}$$

where K is representative of capital inputs, L of labour inputs, E of energy inputs, M of material inputs and S of services purchased in the economy.

3.2.1 Capital inputs

In productivity literature, capital inputs are usually restricted to equipment, structures, land and inventory (Harper, 1997). Linking these elements to the key transport components identified in section 2, it is evident that the physical act of transportation (propulsion) does not incur a capital impact itself. Capital is, however, required to provide the elements that enable transport. Transportation (and particularly freight transportation) is not the only consumer of the energy supplied in South Africa. Based on the existence of other energy markets, it is assumed that the capital cost associated with energy supply is an expense not directly attributable to freight transportation and is excluded from this study. The other two enablers of transport (infrastructure and vehicle supply) could, potentially, be included in this assessment. Providing the infrastructure required for transportation includes spending resources on structures and occupying land that could have been put to alternative use. This can be seen as a negative impact. Provision of the vehicles required for transportation embodies the “equipment” capital inputs. Because the supply of transport infrastructure and vehicles is not a homogeneous process across modes in South Africa, it was decided to exclude these historic capital investments from the assessment of the impacts generated by the contemporary freight system.

3.2.2 Labour inputs

Only the labour inputs associated with transport activity needs to be included. It is assumed that energy, infrastructure and vehicle supply labour inputs are already embedded in the prices used to calculate either the energy input or service input costs, respectively.

3.2.3 Energy inputs

In terms of transport activity, energy inputs comprise the monetary value of all the energy consumed during propulsion of the loaded transport vehicles. It is assumed that the cost of generating and distributing the required amounts of energy is embedded in the energy asking price. The energy inputs associated with infrastructure and vehicle maintenance are assumed to be included in the service input figures.

3.2.4 Material inputs

Material inputs are only included as first level impacts. It refers to items that would typically need to be replaced based on the level of transport activity, for example: tyres.

3.2.5 Service inputs

Maintenance is a service that is provided to support the transport industry. Expenditure on the maintenance of infrastructure and vehicles is assumed to include the labour, energy and some of the materials costs associated with the act of maintenance. Again, due to the existence of external energy markets, maintenance in the energy supply sector is assumed to occur, regardless of the transport sector, and is omitted from this study. Freight transportation can be classified as either being “for reward”, or “not for reward”. Freight transport “for reward” refers to all the freight transport operators whose sole business it is to offer transportation services between producers and their markets. “Not for reward” operators are, typically, the in-house freight services that large producers manage themselves. In general, there is a cost saving involved when companies do not have to outsource their freight transportation. The premium charged by “for reward” operators is included in this study as a service input.

3.3 Environmental impact estimation

As introduced by Lane and Vanderschuren (2010), the term “environment” is seen to represent the core components of nature that sustain life on earth. These components can be categorised as earth (soil and land), water (oceans, fresh water and ground water), air and the earth’s climate. The rationale behind the environmental impact assessment scheme is to combine all the impacts on all of these categories. Impacts are initially measured in the different units best-suited for the specific impact estimation, but eventually the scores are normalised per category and the category scores are summed together. No weighting of impact categories has been done. Due to the nature of environmental impacts, there is a lot of interaction between categories (Figure 3). However, as observed final impact data is used in this study, it is assumed that such interactions are already implicitly represented in the data.

Figure 3 – Environmental impact assessment scheme

3.3.1 Air quality impacts

Air pollution mainly results from emissions released during energy combustion. The emissions most harmful to air quality are: particulates (PM10), sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO) and volatile organic compounds (VOC). Energy combustion has to take place in order to achieve propulsion. The combustion process (transport activity) is thus a major producer of transport related emissions.

Another source of emissions included in this assessment is the emissions generated during the energy supply process. These emissions values tend to be significant, as the energy sources that fuel South Africa’s transport system are mainly derived from fossil fuels (coal and crude oil). Given time, emissions are dispersed in the atmosphere, thus it does not make sense to include emissions generated in the past due to the supply of infrastructure or vehicles.

3.3.2 Climate impacts

Emissions of greenhouse gases (GHGs), such as carbon dioxide (CO_2) and methane (CH_4), contribute to the greenhouse effect and ultimately impact the earth’s climate. These emissions are generated during all transport activities and during the generation of electricity and liquid fuels. Air transportation activity additionally produces water vapour emissions and ozone (O_3), which also affects the climate (Lane and Vanderschuren, 2010). Although GHG emissions are less transient in nature than other air pollutants, the GHG emissions generated from infrastructure and vehicle supply are excluded from this analysis, for the sake of consistency.

3.3.3 Earth impacts

The chief earth-related impacts included are the consumption of non-renewable resources, the quantity of land occupied by infrastructure and the effects of run-off water on soil quality. The quantity of land required for energy and vehicle supply is excluded, as it can be assumed that other industries will occupy the industrial zoned land, should freight transport not require it. Non-renewable resources consumed during the energy supply process are considered in this study, whilst no infrastructure supply, vehicle supply or transport activity related earth impacts are measured.

3.3.4 Water impacts

Water, although a renewable resource, is scarce in South Africa. Excessive consumption of water will incur very negative environmental sustainability impacts. Energy supply is the only transport component with a significant impact on water demand in this analysis. Water pollution (in the form of lake acidification due to acid rain) is a by-product of sulphur dioxide emissions (Gilbert & Perl, 2008) and is included. Run-off water from infrastructure causes ground water pollution and is included in this study.

3.4 Social impact estimation

A review of literature on social impact assessment revealed that social impacts can be classified as impacts either affecting the mental wellbeing of citizens, the material wellbeing of citizens or other socio-economic issues. The combination of these impact classes (after they have been normalised) will inform on the total social impact of freight transportation. Again, no weights are applied, as the relative importance of impacts remains a subjective and contentious issue.

3.4.1 Impacts on mental well-being

The number one impact on mental well-being is the annoyance caused by noise pollution. Not only does noise pollution affect stress levels (ultimately affecting material wellbeing), but it also reduces a person’s ability to concentrate and causes sleep disturbance. This, in turn, affects the person’s productivity at work and their ability to learn in an educational environment (Phillips et al, 2010). In this study only transport activity related noise is considered. The noise created by the energy supply sector is confined to industrial areas and would, thus, not have a profound impact on the mental well-being of citizens (assuming that occupational health and safety guidelines with respect to maximum noise levels are adhered to inside the production facility). As mentioned before, no infrastructure construction or transport vehicle production (and, therefore, their noise impact) is included in this study. Other impacts on mental well-being are of a more qualitative nature and include the aesthetic impacts of transport infrastructure, as well as the disruption to people’s lives due to transport infrastructure maintenance and transport labour union activity.

3.4.2 Impacts on material well-being

Material well-being refers the physical well-being of citizens. The key impacts associated with this criterion are impacts that affect human health. Such impacts cause or contribute to heart disease, cancer, allergies and respiratory diseases. Occurrences of debilitating injuries and fatalities are also included in this category of impacts. These impacts mainly arise due to emissions produced from transport activity, although poor occupational health and safety practice could results in some of these impacts being present in both transport activity and the energy supply sector.

3.4.3 Socio-economic impacts

Socio-economic impacts included in the assessment scheme are employment creation and the risky dependence on non-renewable resources. Being entirely dependent on such resources exposes a country to a high risk of those resources becoming inaccessible (due to cost or scarcity issues), and should ideally be avoided. Transport activity and energy supply greatly influences socio-economic impacts. Infrastructure- and vehicle maintenance related employment opportunities are included in this study. It is worth mentioning that the creation of employment opportunities is a positive social impact, whereas all the other impacts mentioned are negative social impacts.

4 RESULTS FROM THE SOUTH AFRICAN FREIGHT TRANSPORT SYSTEM SUSTAINABILITY ASSESSMENT

Road freight transport is the dominant mode of transport in the country. Knowing this, it is logical to expect road transport to produce the highest level of sustainability impacts of all modes (Figure 4a). The environmental impact of air, water and pipeline transport is extremely low, compared to that of road and rail. This is most likely due to the vast difference in the volume of infrastructure required for road and rail transportation. The results indicate that, with all three “bottom lines” equally weighted, freight transport has a greater impact on the economy than on society or the environment (Figure 4b).

Considering the economic impacts in more detail (Figure 5), it is clear that the infrastructure and vehicle maintenance service costs form the biggest economic input value. Energy costs are the major economic input in road transport. For rail, labour is the greatest economic input. This can be ascribed to the amount of skilled labour required to transport a certain load relative to that of road transport. The expensive nature of materials fit for use in aviation results in material inputs being aviation’s largest economic input.

The combination of high volumes of road and rail transport and the coinciding high infrastructure demand of these modes makes the relative environmental impacts generated by air, water and pipeline transport virtually negligent (Figure 6). Rail transport has a low air quality impact, due to 98% of rail being electrified. It is interesting to note that the environmental impacts are quite evenly spread amongst the four evaluation criteria.

Figure 4b indicates that social impacts are the least prevalent of the “triple bottom lines”. This figure might be somewhat misleading - it is important to remember that there are positive social impacts included in the model. These positive impacts (employment opportunities) effectively cancel out some of the negative impacts present. In air transport the positive effect is just enough to completely outweigh the negative impacts, yielding a small net positive social impact resulting from air freight transportation (Figure 7a). The relatively low level of jobs associated with water and pipeline transportation is not enough to offset the negative socio-economic impact of non-renewable resource dependence due to the energy demand incurred, thus they have a negative net socio-economic impact.

5 CONCLUSIONS AND RECOMMENDATIONS

The strong link between freight transportation and the economy is clear. Any intervention that can lower the freight system's economic input requirements, without adversely affecting output, will go a long way towards improving sustainability in South Africa. Should

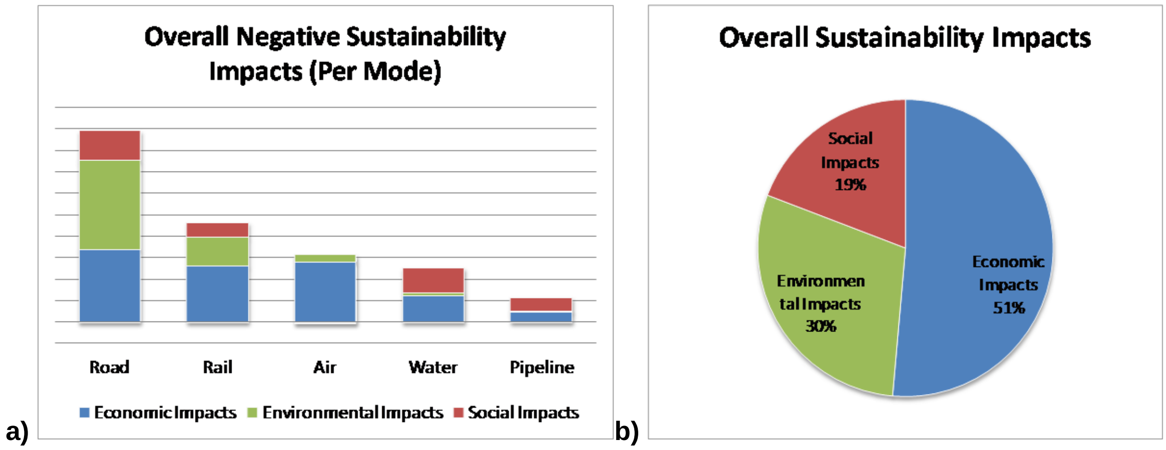

Figure 4 – Results from overall sustainability impact assessment

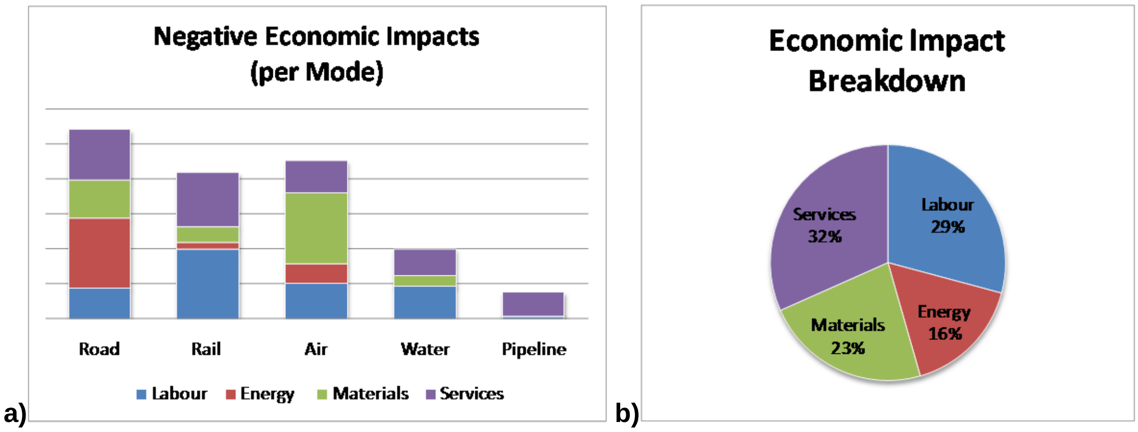

Figure 5 – Results from economic impact assessment

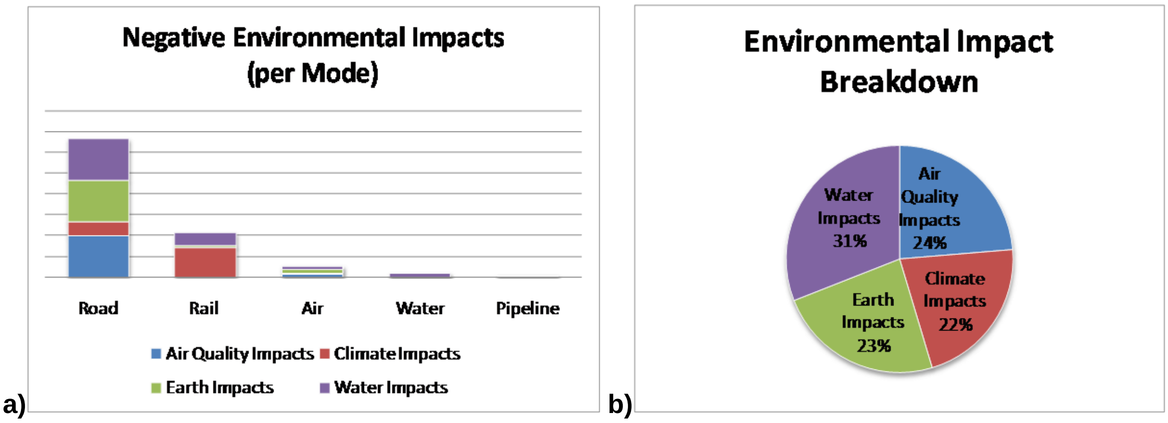

Figure 6 – Results from environmental impact assessment

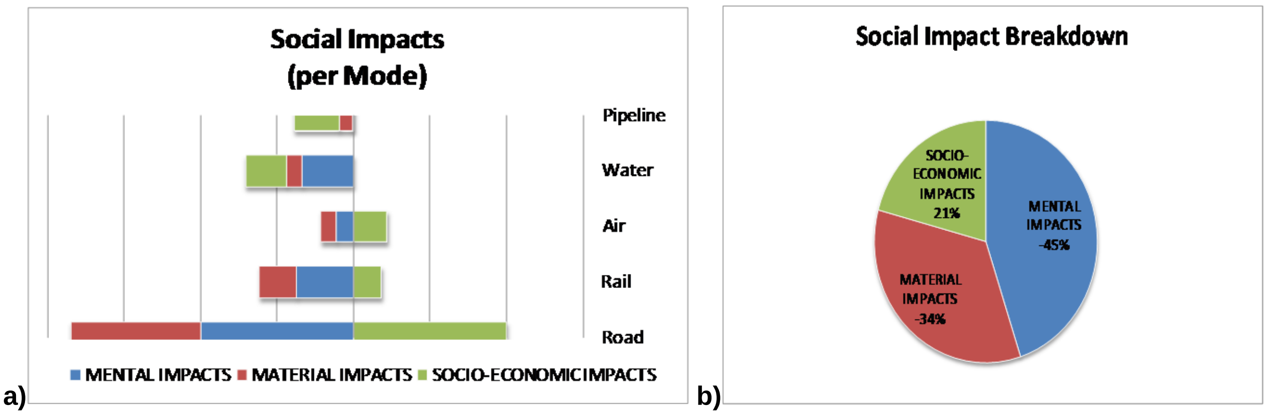

Figure 7 – Results from social impact assessment

such an intervention have positive environmental and social impacts to boot, there should be no excuses hindering implementation as a matter of urgency. Based on the assessment results, one of the main conclusions is that transportation modes which do not require high levels of infrastructure and uses their vehicles and infrastructure in an efficient manner, induce lower economic and environmental impacts. This should be a consideration when future development alternatives are being evaluated. A point to remember is that transport can also have positive impacts. The benefits (such as employment creation) of these impacts should be weighed against their costs (labour inputs) before a decision is made. Any reduction in the volume of road transportation is bound to have a significant impact on the overall sustainability impacts from the South African freight transport system. Road transport is by far the biggest culprit in terms of negative impacts. Furthermore, strategies to curb GHG emissions should focus their attention on rail transportation. It is recommended that this study be repeated every few years, to track and compare the overall performance of the South African freight transport industry. Moreover, a passenger transportation assessment would complement this study.

REFERENCES

Elkington J, 1997. *Cannibals With Forks: The Triple Bottom Line of 21st Century Business*. Capstone, Oxford, pp. 402. ISBN 1-900961-27-X.

Gilbert R and Perl A, 2008. *Transport revolutions – Moving people and freight without oil*, Earthscan, UK. ISBN: 9781844072484

Harper MJ, 1997. *Estimating capital inputs for productivity measurement: an overview of concepts and methods*, Conference on measuring capital stock, March 1997, Canberra, Australia.

Jorgenson AA, 2009. *Transport cost externalities: a discussion paper*, South African Transport Conference, July 2009, Pretoria, South Africa.

Krynauw MN and Cameron JWM, 2003. *National land transport key performance indicators (KPI's) as a measurement of sustainable transport: are we measuring the right things?*, South African Transport Conference, July 2003, Pretoria, South Africa.
Lane TE and Vanderschuren MJWA, 2010. *Evaluating the environmental impact of the South African freight system's energy tendencies*, South African Transport Conference, August 2010, Pretoria, South Africa.

OECD, 2001. *Measuring productivity – OECD Manual*, OECD publications, France. ISBN: 92-64-18737-5. Available online: www.SourceOECD.org

Phillips C, McCarthy M and Barrowcliffe R, 2010. Methods for quantitative health impact assessment of an airport and waste incinerator: two case studies, *Impact Assessment and Project Appraisal*, Vol. 28, pp. 69 – 75.

Richardson BC, 2005. Sustainable transport: analysis frameworks, *Journal of Transport Geography*, Vol. 13, pp. 29 – 39, Elsevier.

Saari S, 2006. *Productivity: Theory and measurement in business*, European Productivity Conference, Aug/Sept 2006, Espoo, Finland.

United Nations World Commission on Environment and Development, 1987. *Our Common Future*. Oxford University Press, Oxford, England.

Zietsman J, Ramani T, Quadrifoglio L and Knowles W, 2009. *Applying sustainable transportation in Texas*, South African Transport Conference, July 2009, Pretoria, South Africa.