

# Socio-environmental performance of transportation systems

Mohammadreza Amiri Khorheh and Frank Moisiadis

*School of Arts and Science, University of Notre Dame, Sydney, Australia, and*

Hoda Davarzani

*Discipline of Business Analytics,*

*University of Sydney Business School, Sydney, Australia*

## Abstract

**Purpose** – The purpose of this paper is to identify and categorize the social and environmental impacts of transportation systems, and address the appropriate solutions to mitigate and manage these impacts in order to achieve sustainability.

**Design/methodology/approach** – This research performs a comprehensive literature review to suggest a framework on socio-environmental impacts of transportation and related solutions. The proposed framework is analyzed through quantitative methods and a survey study in freight transport.

**Findings** – Findings support the direct relation of potential solutions and socio-environmental impacts of transportation. All four categories of solutions (technological, socio-economic and political, cultural and behavioral, and infrastructure related) reveal direct impact on reduction of environmental impacts. However only technological solutions were found to be influential on social impacts of the transportation.

**Originality/value** – To the best of the authors' knowledge there has not been any comprehensive framework covering social and environmental impacts of transportation in the literature. In addition, this paper categorizes potential solutions to enhance socio-environmental performance of the transportation and investigates their effectiveness.

**Keywords** Survey, Mitigation strategies, Social and environmental performance, Sustainable transportation

**Paper type** Research paper

## 1. Introduction

Although the main goal of environmental and social friendly strategies is to reduce the negative impacts of the processes, businesses have also found many potential benefits and competitive advantages through it (Carter and Rogers, 2008; Zhu and Sarkis, 2004; Bai and Sarkis, 2010). Governmental regulations, customer pressures and internationalized business environment have been increasingly drawing the attention of organizations to sustainable development which emphasizes the importance of environmental, social and economic performance in a way that none of these three principles gets neglected or downsized (Seuring and Müller, 2008; Carter and Easton, 2011). Moreover, sustainable development has become a buzzword to high-level political decisions and budgeting, and challenged all the development and investment short- and long-term strategies (Kahn, 2008). Sustainable development provides a guideline to enhance the environment and quality of the human life in all aspects through systemic thinking (Seiffert and Loch, 2005) on eliminating the poverty, promoting equity, managing climate change, fairly distributing the wealth in society, preserving the natural resources and so forth (Velazquez *et al.*, 2011).

In this regard, transportation is an inherent part of any business activity which has been pointed as one of the major reasons for environmental and social problems (Kassens, 2009) during global industrialization. Transport sector is a significant



contributor to greenhouse gas emissions with the global share of 23 percent. The geometric growth of global CO<sub>2</sub> emissions by 45 percent between 1990 and 2007 has magnified the role of this sector (Commission for environmental Cooperation, 2011).

Sustainable freight transport involves employing logistics practices, strategies, tools and materials which eventually reduce the damage of transportation to environment (Rodrigue *et al.*, 2013). Achieving sustainability in freight transport can be most of the times more difficult than other types of transportation first due to the higher importance of cost-effectiveness in freight transportation (Lindholm, 2010) which encourage transport providers to employ low-priced logistics practices e.g. using low-priced fuels or less efficient vehicles. Moreover, freight transport (especially in urban areas) brings all the major issues like land-use planning, congestion, noise and air pollution to surface (Akinbami and Fadare, 1997; Lindholm, 2010; Yim *et al.*, 2011; Browne *et al.*, 2012). All in all, sustainable freight transport implies to range of logistics and supply chain planning and practices which needs to be applied by different stakeholders in a consistent fashion (Rodrigue *et al.*, 2013).

This research presents a theoretical framework on social and environmental performance of the freight transportation systems, as well as the potential mitigation strategies. The interrelation of different building blocks of this theoretical frameworks is investigated through a survey study to answer following research questions:

RQ1. What are the main environmental and social impacts caused by freight transportation?

RQ2. What are the applicable solutions to mitigate and manage these impacts?

RQ3. How are socio-environmental performance and solutions correlated?

To answer these questions, this research suggests a comprehensive categorization of environmental and social impacts of transportation activities based on an extensive literature review (186 papers). Furthermore, a classification on potential solutions and mitigation strategies is addressed. In order to test the goodness-of-fit for the addressed theoretical structures (for both socio-environmental performance and mitigation solutions), a survey is conducted with 650 logistics and transportation managers in Australia. The proposed solutions and strategies are analyzed based on confirmatory factor analysis. In addition to the relation between socio-environmental performance and mitigation solutions, the correlation between environmental and social performance of the transportation, as well as between different solution categories is explored. The analysis in this paper is done through a survey in Australia. Based on a basic search in Scopus database with keyword of “sustainable freight transport” 757 articles can be retrieved, out of which only 5 percent are from authors with Australian affiliation. In addition to the contribution of this paper to sustainable freight transport literature, it provides insights on Australian freight transport.

Australia is responsible for almost 1.5 percent of global greenhouse gas emissions, with transport sector as the second contributor with share of 15 percent (Department of Climate Change and Energy Efficiency, 2012). Carbon pricing/tax scheme was introduced by the Australian Government in 2012 and was in operation until it was repealed by the senate in July 2014. The scheme imposed an initial carbon tax of \$23 per ton of carbon-equivalent emissions in 2012 rising by 5 percent every year in 2013 and 2014. Respondents of our survey have experienced the impact of such regulations on their business, which can provide interesting insights for decision makers in different countries with similar policies in action or planning phase.

The remaining parts of this paper are organized as follows: a literature review on environmental and social performance of the transportation systems is presented in Section 2 followed by a discussion on the interdependence of environmental and social dimensions. Section 3 illustrates potential solutions and strategies to mitigate social and environmental impacts of transportation. The proposed theoretical framework and research model are presented in Section 4 and the applied methods are illustrated in Section 5. After discussion on the results and findings of the research in Section 6, the paper concludes with a brief discussion on practical implications and potential opportunities for future research in Section 7.

2. Environmental and social performance of transportation systems

One of the most highlighted challenges around measuring environmental and social impacts of transportation systems is the transfer of qualitative data to quantitative (Lumsden, 2011) which is not always an easy task particularly when it comes to pure qualitative facts such as visual intrusion.

Environmental and social impacts of transportation systems are categorized as direct, indirect and cumulative (FTA and GDOT, 2011). Direct impacts are those which are made by an action in the real time and place, indirect impacts are caused by an action and show the effects later in time, and cumulative impacts are caused by repeating an action during the time and accumulating until it exceeds the system threshold (FTA and GDOT, 2011). Table I presents the categorization of environmental and social impacts of transportation systems in this research.

Socio-environmental performance		Refers to
Environmental	Air pollution	Emissions (e.g. CO <sub>2</sub> , NO <sub>x</sub> , particles) in terminals and along transport; fuel additives
	Resource and energy consumption	Resource and energy consumptions in transport terminals, during mobility, required for distribution network of resource and energy, and required in infrastructures construction
	Nature and eco-system contamination	Solid waste of fuel producers, transportation, loading and unloading operations; surface water contamination along transport and in terminals; soil contamination along transport and in terminals
	Noise and vibration Land-use problems	Noise in transport terminals and along transport Occupied land for transport purposes; changes in eco-system of land
Social	Accident	Hazards and incidents along transport and in terminals (e.g. while loading, unloading, etc.)
	Congestion	Congestion in terminals and legs of transport; delay because of congestion
	Quality of life	Public health as a result of air pollution, injuries in incidents for operators and users; visual enjoyment in vicinity of terminals and transport routes; fair use of services and opportunities of transport for users; availability of different transport modes for users; affordability for users; reliability of transport as a result of potential delays and damages; safety for operators

Table I.  
Categorization  
of environmental  
and social impacts

## 2.1 Environmental impacts

Environmental impacts are those which directly affect the environment and cause a noticeable level of pollution or damage to air, water, soil, eco-system, natural resources and land.

Table II summarizes the environmental impacts of freight transport, along with their causes and consequences. This research suggests five categories of environmental impacts for freight transport: air pollution, resource and energy consumption, nature and eco-system contamination, noise and vibration and land-use problem. Although some of these categories are interrelated (e.g. the air pollution resulted by energy consumption) but based on the type and origin of the impact, the suggested categorization is solid and comprehensive.

	Causes	Consequences
Air pollution	<p>Vehicles exhausts and smokes</p> <p>Refinery and fuel production activities (Akerman and Hojer, 2006)</p> <p>Construction and maintenance of transportation infrastructures (Plakhotnik <i>et al.</i>, 2005)</p> <p>The main air pollutants are CO<sub>2</sub> (around 80 percent of greenhouse gas), NO<sub>x</sub>, SO<sub>2</sub>, CO, particles and fuel additives</p>	<p>Disturbance to human body (IWWINFRAS, 2004)</p> <p>Global warming (Koroneos and Nanaki, 2007)</p> <p>Climate change (Clark and Lund, 2008; Rodrigue <i>et al.</i>, 2013)</p>
Resource and energy consumption	<p>Usage of energy and resources for mobility</p> <p>Usage of energy and resources for upstream and downstream processes such as infrastructure construction, vehicle production and maintenance, fuel extraction and refinery, and resource distribution activities (IWWINFRAS, 2004)</p>	<p>Consuming non-renewable resources like fossil fuels (Balat, 2008; Chang <i>et al.</i>, 2014; Rodrigue <i>et al.</i>, 2013)</p> <p>Dependency on non-renewable energy as a huge risk to energy accessibility and economy (Clark and Lund, 2008; Piel, 2001)</p>
Eco-system contamination	<p>Fuel, oil, and hazardous materials spillage or leaks (Tegart and Jolley, 2001) and other chemical compounds from either vehicles or transport infrastructure constructions</p> <p>Wastes remaining from freight transport such as wood, paper, plastic and cartons (Rondinelli and Berry, 2000)</p>	<p>Water and soil pollution</p> <p>Solid waste disposal issues</p> <p>Contaminating the eco-system</p>
Noise and vibration	<p>High level of traffic and terminal activities (Janic, 2008)</p> <p>Flow of heavy vehicles (Ferraindiz, 1994)</p> <p>infrastructure construction (Lumsden, 2011)</p>	<p>Disturbance to human body (IWWINFRAS, 2004)</p> <p>Damage to buildings, tunnels and bridges (Campisi and Gastaldi, 1996; Lumsden, 2011)</p>
Land-use problem	<p>Occupation of land by routes, terminals and vehicles</p> <p>Occupation of land for fuel production (Blotnitz and Curran, 2007; Chakraborty, 2006)</p> <p>Changing the pattern of using, structuring and developing the land</p>	<p>Risk to reliability and accessibility of freight transport (Yim <i>et al.</i>, 2011; Lindholm, 2010; Hong and Goodchild, 2014; Rodrigue <i>et al.</i>, 2013)</p> <p>Barrier to routing and planning optimization (Vergragt and Brown, 2007)</p>

**Table II.**  
Causes and  
consequences of  
environmental  
impacts of freight  
transport

2.2 Social impacts

As an inevitable activity of human life, freight transport makes invaluable benefits for the society while on the other side causes several negative social impacts on human life. Two categories of social impacts of freight transport are summarized in Table III and continue further with the last category of impacts, quality of life (QoL).

The last social impact of freight transport, “quality of life”, covers a very extent area rooted in environmental quality, economic situation and social equity (Amekudzi *et al.*, 2009).

Although all previous environmental and social categories affect the QoL in their own way, the main purpose of this category is to include other social aspects of human life which are negatively (and even sometimes positively) influenced by freight transport (Table IV).

**Table III.**  
Causes and  
consequences of  
accident and  
congestion

	Causes	Consequences
Accident	Vehicle incidents (or vehicle and human accident) All other unintended and uncertain events which disrupt regular freight transport such as loss or damage to freight	Potential risks to human life and health Administrative costs of police, justice, healthcare and insurance to the society (IWWINFRAS, 2004) Also causes some environmental impacts such as waste and noise
Congestion	Density and industrialization (Comeau, 2009; Janic, 2008) Peak hour traffics (e.g. early morning loading in terminals) Random reasons like accident or climate condition (Schijndel and Dinwoodie, 2000)	Unproductive transport time and delay (Tapiador <i>et al.</i> , 2009) Risk to reliability and efficiency of freight transport Side environmental effects such as noise and fuel consumption (Kreutzberger <i>et al.</i> , 2003)

**Table IV.**  
Aspects of QoL  
affected by  
transportation  
systems

Factor	Considerations
Public health	Pollution, injuries and fatalities Mental and spiritual aspects Medical costs to society
Visual intrusion	Unattractive infrastructure and scenes like terminals
Accessibility	Access to services, resources, destinations Impacts to land use and congestion
Availability	Being available in desired types and times
Affordability	Serving different financial abilities of transport users
Reliability	Being on time without delays and waiting times
Safety and security	Safe roads, infrastructures and vehicles Safe packages, cargos, layout Required regulations and restrictions due to safety Secure handlings and administration
Convenience and privacy	Being convenience and easy to use Keeping people privacy
Workplace environment	Minimum work conditions for transport service providers such as terminal workers
Wealth and social justice	Distributing the world's resources Making equal opportunities for people

### 2.3 Interrelation between environmental and social impacts

Most of the environmental impacts mentioned in previous section affect each other in different ways. For instance, air pollution is amplified as a result of increased congestion (Colvilea *et al.*, 2004; Janic, 2011). Congestion also increases the noise and fuel consumption (Kreutzberger *et al.*, 2003) and simultaneously decreases the QoL. QoL could also be influenced by accidents, noise and air pollution. There are also researches addressing the interrelation of land use with noise (Chakraborty, 2006), and also with congestion (Krygsman *et al.*, 2004).

Considering the complexity of the interrelation between different impacts of transportation, in a real world, the actual probability, cost and damage of each impact is not clearly measurable and even distinguishable.

## 3. Mitigation policies and solutions

During past decade, any transportation policy or strategy which neglects environmental and social aspects is accounted ineffective (Hensher and Button, 2007). In addition to public awareness of sustainable development, governmental legislations force the transportation sector to effectively diminish the negative impacts on environment and quality of human life.

One of the most significant barriers of adoption and implementation of such policies is scope challenge. The transportation sector by nature has to cope with the adverse policies adopted in local, regional, national and international scopes (Hull, 2008). Local authorities and regional councils have the statutory responsibility on limited dimensions of environmental management (Irving and Moncrieff, 2004) while at a national level, governments pass the appropriate regulations or invest on new technological and behavioral solutions to enhance the environmental and social qualities on a long-term perspective. Moreover, every year there are many new rules and restrictions stated in agreements between the governments, international conventions and contracts in order to control the globalization impacts on the environment and society. As a result, transportation policy makers and actors need to reach a very high level of collaboration to achieve a well-structured sustainable transportation system (Gilbert, 2005). Another challenge of policy adoption and implementation is policy matching. Any environmental and social policy which is not precisely made based on the area characteristics and requirements, is not able to serve its purpose properly (Thynell *et al.*, 2010). This research classifies mitigation solutions and policies into four categories.

### 3.1 Technological solutions

New technology assists socio-environmental performance of freight transport through improving fuel, vehicle and transport service planning.

The effect of new technology on types and quality of the fuels is twofold. First to achieve cleaner fuels with less pollution and dangerous symptoms (Shrestha *et al.*, 2005; Lund and Clark, 2008), and second to shift the fuel consumption to more environmental friendly types, e.g. CNG and LPG, or preferably renewable energies (Tegart and Jolley, 2001). There are still several arguments about the possibility of replacing current fuels with bio-fuels, and actual environmental impacts of bio-fuels (Reinhardt and Falkenstein, 2011).

Vehicle efficiency (Hu *et al.*, 2010; Accorsi *et al.*, 2014) like fuel efficiency (Steg and Gifford, 2005), vehicle weight mitigation (Richardson, 2005) and better engine performance are other contributions of technological advancement. In this fashion, technology may open the opportunity for new vehicles and infrastructures with entirely different mechanisms (Spielman *et al.*, 2008).

Moreover, technology can make a huge difference to freight transport industry through advanced and intelligent ICT solutions for traffic management (Farrington and Ryder, 1993), route planning (Forsyth, 2011), and emission control (Kabashi *et al.*, 2011), freight consolidation (Browne *et al.*, 2012) which need to be updated and improved in parallel with the volume of demand and new sustainable requirements.

ICT improves the environmental performance of freight transport through excess capacity utilization and better distribution systems (Janelle, 1997), as well as more accessible and reliable service planning and mode choice (Casalegno and Chiu, 2008). To implement these sorts of solutions, a close and constant collaboration between researchers and practitioners is needed. Researchers need to come up with more innovative and effective approaches while investors and practitioners need to get more involved in employing advanced solutions.

### 3.2 Socio-economic and political solutions

Socio-economic and political solutions are usually derived by authorities based on regional criteria, governmental regulations and international agreements. Governments and local authorities conduct freight transport industries as a part of public services through their high-level decisions and strategies by which the performance of the whole freight transport industry is highly influenced both in short and long-term perspectives (Bakker and Jacob Trip, 2013). This includes but is not limited to managing transport demand (Akerman and Hojer, 2006; Rodrigue *et al.*, 2013), traffic control (Macario and Marques, 2008) and environment management. Moreover, investment on effective and efficient intermodal transport systems (Campisi and Gastaldi, 1996) can change the freight transport patterns significantly. Another managerial consideration covered by this type of policy refers to defining the fuel and emission standards and rules (Stepp *et al.*, 2009).

Taxes and fees are two regular policies applied by governments to optimize freight transport activities and reduce the number and impacts of shipments (Stelling, 2014). Taxes apply to fuel (Agrawal *et al.*, 2010), road and routes (Kabashi *et al.*, 2011), emissions and vehicle mileage. Fees are the tools used to decrease the number of transport and conduct them into more environmental friendly modes such as fuel price (Richardson, 2005) which encourages freight transport actors to use more efficient fuels and more fuel-efficient vehicles.

Legislations and restrictions are those policies which serve their purpose through prohibiting regulations. Most of these policies target changing the transport habits (Qureshi and Huapu, 2007) to prevent the potential impacts such as congestion and accidents. These policies include weekend prohibition (Lumsden, 2011), controlling the driving hours and traffic regulations (Campisi and Gastaldi, 1996; Stelling, 2014). Freight security and safety regulations are also keys to decrease the social impacts which may affect both stakeholders and society (Rodrigue *et al.*, 2013).

Incentive systems (Santos *et al.*, 2010) are also employed to improve and encourage the environmental friendly transportation systems. These policies target both transport providers and users to optimally form their transport. Some examples of these policies are tax incentives for efficient vehicle manufacturing (Bose and Srinivasachary, 1997), rebates from mass-transit use and vehicle scraping incentives (Kabashi *et al.*, 2011).

### 3.3 Cultural and behavioral solutions

Habits and behavioral patterns influence type, length and frequency of the services. Transport planning and route choosing are mostly handled or affected by drivers or

even sometimes transport buyers based on incomplete or wrong inputs, or even simply an incorrect habit. These people are usually unaware of environmental and social impacts of their choices and decisions.

Cultural and behavioral solutions focus on informing all freight transport stakeholders (Koroneos and Nanaki, 2007) of the importance of environmental and social impacts. Changing these habits and behaviors eventually affects the performance of freight transport from sustainability point of view (Steg and Gifford, 2005).

Freight transport suffers from overcapacity (Lumsden, 2011). In this respect, cultural and behavioral solutions also refer to new arguments on vehicle (or service) sharing, and collaboration between transport providers or buyers to optimize the freight/service, and reduce the frequency of transport (Browne *et al.*, 2012).

Government is responsible to enhance the public awareness of the necessity of mitigating environmental and social impacts of the freight transport. Also transport providers and buyers should adapt their habits and approaches to the benefit of all the players not only themselves.

### 3.4 Infrastructure improvement solutions

Infrastructure improvement Solutions are those which refer to the optimal land-use changes (Macario and Marques, 2008) in order to use the optimum capacity and enhance the accessibility and availability of transportation network.

Improving the routes help mitigating accidents and traffic congestion (Stelling, 2014). Changing the spatial and organizational structure (Akerman and Hojer, 2006) on the other hand enhance the transport patterns and reduce the congestion especially in urban areas. These solutions not only concentrate on integration of land-use planning and transportation systems (Richardson, 2005), but also refer to modifying the road and rail characteristics (Sandvik, 2005) in order to allow higher occupancy vehicle lanes (Kabashi *et al.*, 2011), and aiming less environmental and social impacts by decreasing the frequency. Governments, traffic planners, traffic controllers, and transport and land-use policy makers each have significant roles to amend the routes and paths.

## 4. Research model

As illustrated in previous sections, mitigation policies and solutions can be categorized into four main groups of technological, socio-economical and political, cultural and behavioral and infrastructure related. Table V summarizes the implications of these solutions and potential aspects of sustainable performance to influence.

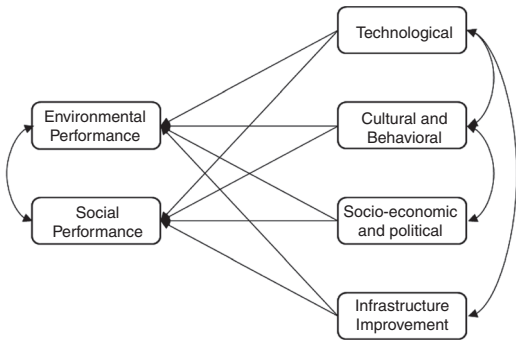
Based on the investigated literature all four categories of mitigation solutions can be considered as potential antecedents of environmental and social performance of the transportation (see examples of detailed implications in Table V). In addition, literature (e.g. Stelling, 2014; Haynes *et al.*, 2005; Qureshi and Huapu, 2007) supports the potential coordination between some of them, for example infrastructure improvement category can theoretically be correlated with technological solutions. Introducing cleaner and fuel-efficient vehicles (e.g. high-capacity vehicles such as multiple/double-trailer trucks) can be more effective if the conditions of roads are at the same time improved and they can support their requirements (e.g. road width and safety aspects). Finally as discussed earlier in Section 2.3, the interrelation between social and environmental dimensions is reflected in the developed theoretical model (Figure 1). The proposed relations are checked for validity in following steps. First, the proposed structure for environmental and social performance of the transportation is checked for validity. In order to do so, exploratory factor analysis and second-order confirmatory factor



**Table V.**  
Summarized  
mitigation solutions  
and their potential  
influence on  
socio-environmental  
performance

Solutions category	Implications	Potential influence on
Technological	Cleaner fuels and renewable energy sources Cleaner and more efficient vehicles ICT-based planning, management and control system e-services and e-solutions to replace unnecessary travels	Environmental and social performance (through air pollution, energy consumption, congestion, quality of life)
Socio-economic and political	Management and investment in public services Taxes and fees Legislations and restrictions Incentive systems	Environmental and social performance (through congestion and quality of life)
Cultural and behavioral	Provide transport users with information on environmental impacts Changing lifestyles and transport habits Sharing vehicles and transport collaboration	Environmental and social performance (through air pollution, energy consumption, nature, noise, accident, congestion, quality of life)
Infrastructure improvement	Land-use optimization Spatial and organizational modifications Higher occupancy vehicle lanes Improving road characteristics	Environmental and Social performance (through air pollution, energy consumption, nature, land use, quality of life)

**Figure 1.**  
Theoretical  
framework



analysis techniques are employed and the structure is checked for validity and reliability. Similar process is performed for evaluating the validity of the proposed structure and classification for mitigation solutions. AMOS provides the opportunity to estimate the latent variables, which are used to test the presented relations between socio-environmental performance and mitigation solutions in Figure 1.

**5. Methods**

*5.1 Sample and procedures*

Scope of this study is limited to freight transport (international and domestic with all modes), our data gathering and analysis do not include passengers and public transport. Total freight transport volume in Australia has had a sharp increase over the past four decades.

According to the Bureau of Infrastructure, Transport and Regional Economics, BITRE (2014), the freight volume has grown by almost 60 percent since 2000. This dramatic growth in Australia's freight transport is expected to continue over the next two decades. Commitment to sustainable development has been highlighted in Australia's National Strategy for Ecologically Sustainable Development. Aligned with this strategy, potential impacts of freight transport growth cannot be neglected. The National Pollutant Inventory reports the level of different pollutants for transport industry sector (2012-2013), e.g. carbon monoxide 1.4 ton; lead and compounds 1500 kg, oxides of nitrogen 5.1 ton; and sulfur dioxide 1.6 ton (National Pollutant Inventory, 2013). These numbers can be significantly higher if appropriate sustainable development policies are not in place. Air pollution is not the only concern for Australian Government. Level of noise and land use are also among the other aspects considered by nation-wide and state-wide authorities in Australia (Western Australian Planning Commission, 2009). The estimated increase of surface temperatures in Australia by 1°C (Seiffert and Loch, 2005) and 24 percent increase in days of extreme weather by 2030 (SCOTI, 2012) highlight the importance of sustainably managing freight transport.

The empirical data for this study was gathered from participants of two logistics and transportation gatherings in Australia in late 2013. In total, 650 experts were contacted by e-mail and asked to fill the electronic questionnaire. After two weeks, a reminder message was sent to all the respondents to increase the response rate. In total, 34 e-mails were failed, and 139 usable responses were received (21 percent response rate).

In terms of area of work, 43 percent of the respondents were logistics and transport service provider, 53 percent logistics/transport user, and the remaining 4 percent classified as others (e.g. researchers and academics). Respondents indicated their positions as consultant (7 percent), operations manager (31 percent), supply chain/logistics manager (38 percent), logistics/transport analyst (16 percent) and others (8 percent). The data were checked for bias based on the respondents' area of work and their position. The ANOVA test indicated no significant difference between the data from different respondent groups.

Majority of the literature with special focus on social/environmental performance of the transport and mitigation strategies, adopt case study as their research method. For example, Browne *et al.* (2012), Santos *et al.* (2010) and Stelling (2014) used empirical examples to illustrate different aspects of social/environmental performance of the transport systems and the employed mitigation strategies in different geographical regions. Unlike the previous literature, this paper chooses survey as the main analysis method. It provides the opportunity to form and test different hypotheses on effectiveness of the mitigation solutions as well as examining the correlation between social and environmental performance, and mitigation solutions.

## 5.2 Measures

The measurement of all constructs includes different indicators which were suggested by previous research. List of the constructs and respective questions are exhibited in Table VI (with five-point Likert scale). For questions on environmental and social impacts, respondents were asked to rate each item based on their experience in their company, with the responses ranging from 1 (very low) to 5 (very high). For the constructs of technological and cultural and behavioral solutions, they were asked to indicate the status of their company regarding each strategy, with the response options of "not in the company's strategy" (1), "in planning process" (2), "planned but not implemented" (3), "planned and in the beginning of the implementation" (4), and "planned

MEQ 26,6		
	Construct	Questions
836	<i>Social and environmental performance</i>	
	Air pollution	1-3
	Energy consumption	4-7
	Nature and eco-system	8-13
	Noise	14-15
	Land use	16-17
	Accident	18-19
	Congestion	20-22
	Quality of life	23-33
	<i>Mitigation strategies and solutions</i>	
	Technical	34-38
	Cultural and behavioral	39-41
	Socio-economic and governmental	42-44
	Infrastructure	45-48
<b>Table VI.</b> List of the constructs and respective questions in the survey		

and implemented” (5). In terms of socio-economic and governmental and infrastructure solutions, respondents indicated how much their company has been influenced each policies and strategy, with the responses ranging from 1 (very low) to 5 (very high). Please see the Appendix for the survey.

## 6. Results

### 6.1 Exploratory factor analysis and developing rival models

To check whether the proposed model for measurement of environmental and social impacts is backed up by the empirical results obtained from the study, an exploratory factor analysis was done, using principal axis factoring with promax rotation in SPSS 18. Ten factors with eigenvalue of more than one emerged; **five of these factors (air pollution, energy consumption, noise, land use, congestion)** and their indicators were the same as the suggested constructs in Table VI but indicators of three constructs (nature and eco-system, accident, QoL) were divided into five factors (presented in Table VII as solid waste, water and soil contamination, safety, reliability and affordability, public health). Reviewing the questions indicates the emerged factors are meaningful and for the rest of analysis a rival model with ten factors is also considered in the paper.

Table VII presents the constructs and related questions in the rival model. Exploratory factor analysis with principal axis factoring and promax rotation was also performed for mitigation strategies and solutions. Four factors with an eigenvalue

	Social and environmental performance			
	Construct	Questions	Construct	Questions
<b>Table VII.</b> Rival model of the environmental and social performance	Air pollution	1-3	Land use	16-17
	Energy consumption	4-7	Safety	18-19, 31-32
	Solid waste	8-9	Congestion	20-22
	Water and soil contamination	10-13	Reliability and affordability	26-30, 33
	Noise	14-15	Public health	23-25

above one emerged. Based on the resulted loadings, the indicators corresponding to the same construct load on a single factor. This is an indication of the validity for the proposed structure of mitigation strategies and solutions.

The results also reveal relatively low loading for variable 46, this variable should be investigated thoroughly in later stages of the confirmatory factor analysis.

A set of variables is suitable for factor analysis if their correlation matrix has many sizable correlations. Several correlations in excess of 0.3 were found in the correlation matrix of the observed variables for both impacts, and solutions. The anti-image correlation matrix was also used to assess the sampling adequacy of each variable. Measure of the sampling accuracy was above the acceptable level of 0.5 for all variables. Kaiser-Meyer-Olkin (KMO)[1] measure of sampling adequacy and Bartlett's test of sphericity[2] were used to confirm the factorability of the matrix for both impacts, and solutions (Table VIII).

### 6.2 Confirmatory factor analysis: reliability and internal consistency

To obtain a sound judgment on the structural relationships between the developed constructs, a second-order factor analysis for the proposed structure of sustainable performance of the transportation and a first-order factor analysis for the structure of the mitigation solutions were conducted. Prior to carrying out these analysis, normality of all the 48 indicators were checked. The results show most of the observed variables are significantly different from normal distribution, which advice against using the maximum likelihood method. Instead, generalized least squares was found to be an appropriate method to estimate the model. Both developed models based on literature (with eight constructs, code M1 in Table IX) and exploratory factor analysis (with ten constructs, code M3 in Table IX) were tested in AMOS 18. Loadings of the variables in these two models were inspected and variables with loadings of less than 0.4 were removed. Table IX presents the summary of model fit indices to compare these models. Model M4 represents the best values for most of the fit indices and all of them are in acceptable range. M4 (Figure 2) is the chosen structure for the rest of analysis in this paper. Estimated loadings are presented in Table X. In order to differentiate factors of each level in Table X, directly estimated factors from the observed variables are called first-order factors and next level of factors are referred to as second-order factors. For the second-order factors, air pollution has the highest loading to environmental impacts which is followed by energy consumption as the second highest loading. Among the social impacts, congestion has the highest loading although loadings of the rest of the factors are relatively close. The Cronbach's  $\alpha$  coefficient has also been independently

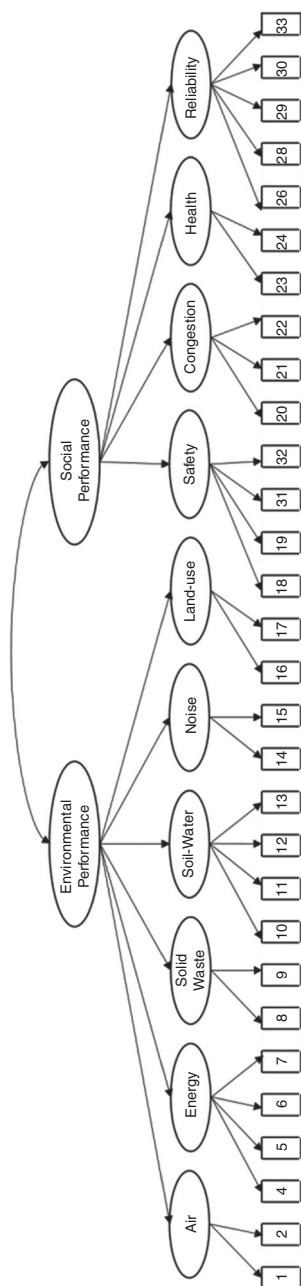
	Structure of the impacts	Structure of the solutions
Kaiser-Meyer-Olkin measure of sampling adequacy	0.784	0.642
<i>Bartlett's test of sphericity</i>		
Approx. $\chi^2$	1,630.695	369.705
df	528	105
Sig.	0.000	0.000

**Table VIII.**  
KMO and  
Bartlett's test

**Table IX.**  
Summary results of  
confirmatory factor  
analysis for rival  
models

Code	Rival models	Removed variables	$\chi^2$	df	$\chi^2/\text{df}$	RMSEA	RMR	GFI	AGFI	CFI
<i>Environmental and social impacts</i>										
MM1	Literature model	–	842.56*	487	1.73	0.060	0.083	0.781	0.735	0.817
MM2	Modified Literature model	3, 25, 27, 31, 32	518.09*	342	1.51	0.045	0.066	0.821	0.768	0.896
MM3	EFA model	–	868.32*	487	1.78	0.052	0.074	0.796	0.746	0.866
MM4	Modified EFA model	3, 25, 27	732.52*	397	1.85	0.050	0.068	0.830	0.786	0.914
<i>Mitigation strategies and solutions</i>										
SS1	Literature model	–	103.84**	84	1.24	0.041	0.062	0.916	0.879	0.929
SS2	Modified model	46	90.20**	71	1.27	0.044	0.063	0.920	0.882	0.931

**Notes:** EFA, exploratory factor analysis; RMSEA, root mean square error of approximation; RMR, root mean residual; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; CFI, comparative fit index. \* $p < 0.05$ , \*\* $p < 0.001$



**Figure 2.**  
Validated structure

Factor <sup>a</sup>	Second-order factor	Loading factor		Factor <sup>a</sup>	Second-order factor	Loading factor	
<i>Second-order factors</i>							
Air	Environmental	0.92***		Land use	Environmental	0.73 <sup>b</sup>	
Energy	Environmental	0.84***		Safety	Social	0.42 <sup>b</sup>	
Solid Waste	Environmental	0.41*		Congestion	Social	0.55*	
Soil-Water	Environmental	0.43*		Health	Social	0.51*	
Noise	Environmental	0.68***		Reliability	Social	0.4*	
Indicator	Factor <sup>a</sup>	Loading factor	Cronbach's $\alpha$	Indicator	Factor <sup>a</sup>	Loading factor	Cronbach's $\alpha$
<i>First-order factors</i>							
1	Air	0.61**	0.687	18	Safety	0.62***	0.751
2	Air	0.81 <sup>b</sup>		19	Safety	0.75***	
4	Energy	0.75***	0.813	31	Safety	0.67***	
5	Energy	0.57***		32	Safety	0.57 <sup>b</sup>	
6	Energy	0.71***		20	Congestion	0.88***	0.796
7	Energy	0.63 <sup>b</sup>		21	Congestion	0.80***	
8	Solid waste	0.92*	0.716	22	Congestion	0.79 <sup>b</sup>	
9	Solid waste	0.56 <sup>b</sup>		23	Health	0.54***	0.762
10	Soil-water	0.47**	0.763	24	Health	0.97 <sup>b</sup>	
11	Soil-water	0.49**		26	Reliability	0.69***	0.741
12	Soil-water	0.54**		28	Reliability	0.78***	
13	Soil-water	0.63 <sup>b</sup>		29	Reliability	0.74***	
14	Noise	0.81***	0.703	30	Reliability	0.63***	
15	Noise	0.48 <sup>b</sup>		33	Reliability	0.83 <sup>b</sup>	
16	Land use	0.57***	0.711				
17	Land use	0.80 <sup>b</sup>					

**Table X.**  
Loadings of factors  
and indicators

**Notes:** <sup>a</sup>Air, air pollution; Energy, energy consumption; Soil-Water, soil and water contamination; Health, public health; Reliability, reliability and affordability. <sup>b</sup>Non-calculated *t*-value (parameter set as 1). \**p* < 0.05; \*\**p* < 0.01; \*\*\**p* < 0.001

calculated for each of the ten factors, so as to check the degree of internal consistency. The values of this coefficient for all the factors is above the acceptable limit. The obtained results on quality of fit and internal consistency provide enough evidence to confirm the proposed structure for environmental and social impacts.

The performed exploratory factor analysis on the indicators of mitigation solutions and strategies provided a primary evidence on validity of the proposed structure. At this stage of the analysis, fitness of the model is evaluated based on confirmatory factor analysis. The conducted confirmatory factor analysis on the structure of mitigation strategies and solutions revealed low loading for variable 46, which also confirms the result of exploratory factory analysis in the previous step. In order to achieve higher quality fit, variable 46 has been removed to create the rival model of code S2 in Table IX. The modified structure (code S2) has very good values for all the fit indices and the model is accepted for further steps of the analysis. Presented loadings in Table XI are not very high but all in the acceptable rage. The Cronbach's  $\alpha$  has also been independently calculated for each factor; high value of the Cronbach's  $\alpha$  for all the factors indicates the internal consistency. All the obtained results on the aforementioned indices provide enough evidence to confirm the proposed structure for mitigation solutions and strategies.

**Table XI.**Loadings of factors  
and indicators for  
mitigation solutions  
and policies

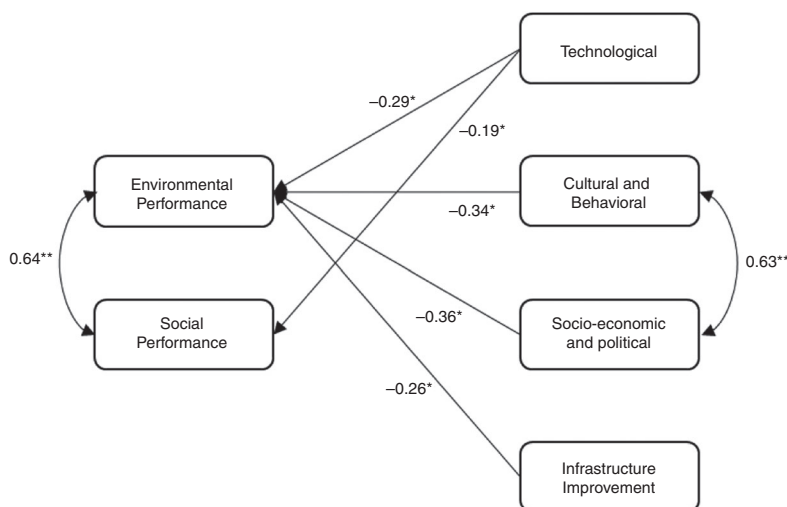
Indicator	Factor	Loading factor	Cronbach's $\alpha$
34	Technological	0.44 <sup>a</sup>	0.875
35	Technological	0.6***	
36	Technological	0.4**	
37	Technological	0.55***	
38	Technological	0.76***	0.748
39	Socio-economic and governmental	0.43 <sup>a</sup>	
40	Socio-economic and governmental	0.41*	
41	Socio-economic and governmental	0.6**	
42	Cultural	0.63 <sup>a</sup>	0.688
43	Cultural	0.61***	
44	Cultural	0.62***	
45	Infrastructure	0.71 <sup>a</sup>	
47	Infrastructure	0.76***	0.759
48	Infrastructure	0.72***	

**Notes:** <sup>a</sup>Non-calculated *t*-value (parameter set as 1). \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

### 6.3 Model test

One of the objectives of this research was to test the effectiveness of mitigation strategies and solutions. Value of the unobserved variables (factors) were estimated based on regression imputation in AMOS to provide the opportunity of testing the relationships. The theoretical framework of Figure 1 was tested in AMOS. The presented relationships in Figure 3 were confirmed and the suggested structure was supported based on different model fit indices ( $\chi^2 = 40.382$ ,  $df = 8$ ,  $RMSEA = 0.7$ ,  $RMR = 0.014$ ,  $GFI = 0.910$ ,  $AGFI = 0.865$ ,  $CFI = 0.913$ ).

Resulted outcomes support existence of a strong correlation (0.64) between environmental and social impacts. The estimated correlation is supported with  $p$ -value of 0.001. The strong correlation (0.63) between “cultural and behavioral” and



**Notes:** \* $p < 0.05$ ; \*\* $p < 0.001$

**Figure 3.**  
Framework of the  
relation between  
socio-environmental  
performance and  
mitigation solutions



“socio-economic and political” solutions is also supported at similar significance level. The literature suggests existence of correlation between other solution categories (e.g. Stelling, 2014; Haynes *et al.*, 2005; Qureshi and Huapu, 2007) which was also reflected in the proposed theoretical framework in this paper (Figure 1), but significance of these correlations has not been confirmed in our study. Based on the investigated literature it was expected to see significant relation between employment of mitigation solutions and environmental and social performance of the transportation. Results of the study do not support these relations for all the mitigation solutions. All the four categories of solutions reveal significant influence on environmental impacts of transportation. Employment of the illustrated solutions and strategies can play considerable role in decreasing the environmental impacts. The results indicate socio-economic and political solutions are the most effective ones while infrastructure improvement has the least influence. Technological solutions is the only category with significant direct impact on both environmental and social performance of the transportation, although the regression weight of the technological solutions and social impacts is relatively lower than rest of the estimated values.

## 7. Conclusion

This paper addresses a comprehensive categorization of socio-environmental performance of the transportation based on a literature review. For this purpose first all environmental and social impacts of freight transportation were categorized into eight categories: air pollution, resource consumption, eco-system contamination, noise and vibration, land-use problem, accident, congestion, and QoL. The first five categories are mostly considered as environmental and the last three ones as social while there are interrelations between them. Then the paper suggests four groups of mitigation solutions to decrease the impacts and achieve more environmental and social friendly freight transportation.

The proposed model for classification of the performance indicators, mitigation solutions and their interrelation has been investigated using survey research method. Performed exploratory and confirmatory factor analysis resulted in minor modification of the initial model although the model has been validated and verified. In addition, four categories of mitigation solutions and strategies were extracted from literature and tested based on exploratory and confirmatory factor analysis. Findings of our analysis support potential impacts of the technological solutions on both environmental and social performance of the transportation. The three remaining categories of solutions (behavioral and cultural solutions, socio-economic and political strategies, and infrastructure improvement) have been found to only influence environmental performance. Correlation of environmental and social performance was also suggested in the literature (e.g. Colvilea *et al.*, 2004; Janic, 2011; Kreutzberger *et al.*, 2003; Chakraborty, 2006; Krygsman *et al.*, 2004), which has been supported by the findings of this research. To the best of our knowledge, this is the first attempt to present a comprehensive classification for socio-environmental impacts of freight transport and related mitigation solutions. Unlike previous papers in the literature (e.g. Browne *et al.*, 2012; Santos *et al.*, 2010; Stelling, 2014), this research considers the potential correlation between social and environmental performances as well as between mitigation solutions.

From a business perspective highlighting the significance of environmental and social responsibilities, this paper suggests that like all other business actors, logistics and transportation sector is no longer fully tied to economic objectives. The principles of sustainable development made the business environment to adopt more

consideration on common issues such as global warming, lack of equity, unfair distribution of wealth and so forth. This research addresses this common issues and mitigation strategies that promote the human life conditions in both environmental and social points of view.

### 7.1 *Practical implications*

To achieve a better environmental and social quality in logistics and transportation, four groups of mitigation solutions have been addressed and described. Investing on cleaner fuels and more efficient engines, improving and optimizing transportation planning and management leading to minimizing unnecessary transports and decreasing the frequency, are the main and most effective approaches comprised in technological solutions.

Rather than technological solutions, governmental policies and high-level rules and restrictions make the transport provider to put the environmental and social responsibilities in a higher priority. Emission tax and other type of restrictions lead to lower transport frequency and eventually the better environmental conditions. Furthermore, incentive policies may encourage the actors to invest more on service improvement and optimization which benefit the society.

Lack of knowledge and understanding on consequences of their decisions and actions, make the businesses never think out of the box and invest on the better way of conducting their activities. Providing this information is the first step to influence the common culture and behavior in transportation sector. There are massive opportunities of collaboration between transport providers and users such as vehicle/container sharing which lead to better use of transport capacity and lower frequency. Cultural and behavioral solutions help transport providers and users to improve their approaches in both demand and supply channels.

The last group of solutions is infrastructure and route improvement including all the actions to make the roads, railways, airways and sea routes more efficient in terms of lower frequency, lighter traffic, less hazard, more availability and accessibility, and minimum negative impacts on human life.

Our findings support the direct impact of all four categories of mitigation strategies on environmental performance, although the achieved regression weights are not very high but still significant. On the contrary, only technological solutions reveal significant direct influence on social performance. Governments and decision making organizations may find the achieved results interesting as they shed light on the effectiveness of the advised plans.

In regards to implementation, government and other strategic decision makers have the major roles in terms of investment, training, legislation, planning and management and supervision. Transport providers and users are other players with a heavy load on their shoulders to adapt their practices to the benefit of public instead of their business. Moreover, in order to continuously make improvement, the gaps between research and practices should be filled.

### 7.2 *Limitations and suggestion for future research*

Analyzing the performance of a transportation activity needs a solid understanding of the type and nature of that activity including the context, transport provider and user, and supporting systems. In this regards, future research should focus on the role of key details such as transportation modes, freight types, volumes and vehicle types in socio-environmental performance of the transportation systems.

Moreover transport activities are generally categorized into two main categories: freight movements and passenger travel. Although this research has mainly concentrated on freight transport, passenger travel also constitutes a very large number of processes and activities, causing almost identical social and environmental impact on human lives. Testing the accomplishments of this research for passenger travel is another valuable research opportunity.

This research suggested four main groups of solution to minimize the effects of transportation systems on the environment and society. Although these solutions have been repeatedly supported by literature, it does not mean that their feasibility, efficiency and effectiveness are not questionable. Evaluating the suggested solutions based on the type and context of the transportation systems is another direction for future research.

### Notes

1. The KMO measure of sampling adequacy is an index for comparing the strength of the observed correlation coefficients to the strength of the partial correlation coefficients. Large values for KMO measures indicate suitability of factor analysis method.
2. Bartlett's test of sphericity is used to test the hypothesis that variables in the population correlation matrix are uncorrelated.

### References

- Accorsi, R., Manzini, R. and Ferrari, E. (2014), "A comparison of shipping containers from technical, economic and environmental perspectives", *Transportation Research Part D: Transport and Environment*, Vol. 26, pp. 52-59.
- Agrawal, A.W., Dill, J. and Nixon, H. (2010), "Green transportation taxes and fees: a survey of public preferences in California", *Transportation Research Part D*, Vol. 15 No. 4, pp. 189-196.
- Akerman, J. and Hojer, M. (2006), "How much transport can the climate stand? – Sweden on a sustainable path in 2050", *Journal of Energy Policy*, Vol. 34 No. 14, pp. 1944-1957.
- Akinbami, J.F.K. and Fadare, S.O. (1997), "Strategies for sustainable urban and transport development in Nigeria", *Transport Policy*, Vol. 4 No. 4, pp. 231-245.
- Amekudzi, A.A., Khisty, C.J. and Khayesi, M. (2009), "Using the sustainability footprint model to assess development impacts of transportation systems", *Transportation Research Part A*, Vol. 43 No. 4, pp. 339-348.
- Bai, C. and Sarkis, J. (2010), "Addressing key sustainable supply chain management issues using rough set methodology", *Management Research Review*, Vol. 33 No. 12, pp. 1113-1127.
- Bakker, S. and Jacob Trip, J. (2013), "Policy options to support the adoption of electric vehicles in the urban environment", *Transportation Research Part D: Transport and Environment*, Vol. 25, pp. 18-23.
- Balat, M. (2008), "Potential importance of hydrogen as a future solution to environmental and transportation problems", *International Journal of Hydrogen Energy*, Vol. 33 No. 15, pp. 4013-4029.
- BITRE (2014), "Freightline 1 – Australia freight transport overview", in *Bureau of Infrastructure, Transport and Regional Economics (BITRE)*, Department of Infrastructure and Regional Development, Canberra, available at: [www.bitre.gov.au/publications/2014/freightline\\_01.aspx](http://www.bitre.gov.au/publications/2014/freightline_01.aspx) (accessed February 2015)
- Blottnitz, H.V. and Curran, M.A. (2007), "A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective", *Journal of Cleaner Production*, Vol. 15 No. 7, pp. 607-619.

- Bose, R.K. and Srinivasachary, V. (1997), "Policies to reduce energy use and environmental emissions in the transport sector", *Journal of Energy Policy*, Vol. 25 Nos 14-15, pp. 1137-1150.
- Browne, M., Allen, J., Nemoto, T., Patier, D. and Visser, J. (2012), "Reducing Social and environmental impacts of urban freight transport: a review of some major cities", *Procedia – Social and Behavioral Sciences*, Vol. 39, pp. 19-33.
- Campisi, D. and Gastaldi, M. (1996), "Environmental protection, economic efficiency and intermodal competition in freight transport", *Transportation Research Part C*, Vol. 4 No. 6, pp. 391-406.
- Carter, C.R. and Easton, P.L. (2011), "Sustainable supply chain management: evolution and future directions", *International Journal of Physical Distribution and Logistics Management*, Vol. 41 No. 1, pp. 46-62.
- Carter, C.R. and Rogers, D.S. (2008), "A framework of sustainable supply chain management: moving toward new theory", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 5, pp. 360-387.
- Casalegno, F. and Chiu, D. (2008), *White Paper on Sustainable Transportation*, MIT Mobile Experience Lab, Cambridge, MA.
- Chakraborty, J. (2006), "Evaluating the environmental justice impacts of transportation improvement projects in the USA", *Transportation Research Part D*, Vol. 11, pp. 315-323.
- Chang, Y.-T., Park, H.-S., Jeong, J.-B. and Lee, J.-W. (2014), "Evaluating economic and environmental efficiency of global airlines: a SBM-DEA approach", *Transportation Research Part D: Transport and Environment*, Vol. 27, pp. 46-50.
- Clark, W.W. and Lund, H. (2008), "Integrated technologies for sustainable stationary and mobile energy infrastructures", *Utilities Policy*, Vol. 16 No. 2, pp. 130-140.
- Colville, R.N., Kaura, S., Britterb, R., Robinsc, A., Belld, M.C., Shallcrosse, D. and Belcher, S.E. (2004), "Sustainable development of urban transport systems and human exposure to air pollution", *Science of the Total Environment*, Vols 334-335, pp. 481-487.
- Comeau, C. (2009), "Moving beyond the automobile: multimodal transportation planning in Bellingham, Washington", *Practicing Planner*, Vol. 7 No. 3, pp.1-16.
- Commission for environmental Cooperation (2011), *Destination Sustainability: Reducing Greenhouse Gas Emissions from Freight Transport in North America*, Communications Department of the CeC Secretariat, Montreal, available at: [www3.cec.org/islandora/en/item/4237-destination-sustainability-reducing-greenhouse-gas-emissions-from-freight-en.pdf](http://www3.cec.org/islandora/en/item/4237-destination-sustainability-reducing-greenhouse-gas-emissions-from-freight-en.pdf) (accessed February 2015).
- Department of Climate Change and Energy Efficiency (2012), *Australia's Emissions Projections 2012*, DCCCE, Canberra.
- Farrington, J.H. and Ryder, A.A. (1993), "The environmental assessment of transport infrastructure and policy", *Journal of Transport Geography*, Vol. 1 No. 2, pp. 102-118.
- Ferraindiz, J.V.C. (1994), "Integrated freight transportation centers; influence on the decrease in environmental effects in urban areas", *The Science of the Total Environment*, Vols 146-147, pp. 59-65.
- Forsyth, P. (2011), "Environmental and financial sustainability of air transport: are they incompatible?", *Journal of Air Transport Management*, Vol. 17 No. 1, pp. 27-32.
- FTA and GDOT (2011), "Documentation in support of an environmental assessment", Albany Multimodal Transportation Center, Georgia Department of Transportation, Dougherty County, GA.
- Gilbert, R. (2005), *Defining Sustainable Transportation: Prepared for Transport Canada*, The Centre for Sustainable Transportation, University of Winnipeg, Winnipeg.
- Haynes, K.E., Gifford, J.L. and Pelletiere, D. (2005), "Sustainable transportation institutions and regional evolution: global and local perspectives", *Journal of Transport Geography*, Vol. 13 No. 3, pp. 207-221.

- Hensher, D.A. and Button, K.J. (2007), "Book review: handbook of transport and the environment", *European Journal of Transport and Infrastructure Research*, Vol. 7 No. 1, pp. 63-66.
- Hong, J. and Goodchild, A. (2014), "Land use policies and transport emissions: modeling the impact of trip speed, vehicle characteristics and residential location", *Transportation Research Part D: Transport and Environment*, Vol. 26, pp. 47-51.
- Hu, X., Chang, S., Li, J. and Qin, Y. (2010), "Energy for sustainable road transportation in China: challenges, initiatives and policy implications", *Journal of Energy*, Vol. 35 No. 11, pp. 4289-4301.
- Hull, A. (2008), "Policy integration: what will it take to achieve more sustainable transport solutions in cities?", *Journal of Transport Policy*, Vol. 15 No. 2, pp. 94-103.
- Irving, P. and Moncrieff, I. (2004), "Managing the environmental impacts of land transport: integrating environmental analysis with urban planning", *Science of the Total Environment*, Vols 334-335, pp. 47-59.
- IWWINFRAS (2004), "External costs of transport update study final report", UIC, Zurich/Karlsruhe.
- Janelle, D.G. (1997), "Sustainable transportation and information technology: suggested research issues", *Journal of Transport Geography*, Vol. 5 No. 1, pp. 39-40.
- Janic, M. (2008), "An assessment of the performance of the European long intermodal freight trains (LIFTS)", *Transportation Research Part A*, Vol. 42 No. 10, pp. 1326-1339.
- Janic, M. (2011), "Assessing some social and environmental effects of transforming an airport into a real multimodal transport node", *Transportation Research Part D*, Vol. 16 No. 2, pp. 137-149.
- Kabashi, S., Bekteshi, S., Ahmetaj, S., Kabashi, G., Blinc, R., Zidansek, A. and Slaus, I. (2011), "Greenhouse gas and air pollution emissions and options for reducing from the Kosovo transportation sector-dynamic modelling", *Management of Environmental Quality: An International Journal*, Vol. 22 No. 1, pp. 72-88.
- Kahn, R. (2008), "From education for sustainable development to ecopedagogy: sustaining capitalism or sustaining life?", *Green Theory & Praxis: The Journal of Ecopedagogy*, Vol. 4 No. 1, pp. 1-14.
- Kassens, E. (2009), "Sustainable transportation: an international perspective", *MIT Journal of Planning*, Vol. 9, pp. 6-9.
- Koroneos, C. and Nanaki, E. (2007), "Environmental assessment of the Greek transport sector", *Journal of Energy Policy*, Vol. 35 No. 11, pp. 5422-5432.
- Kreutzberger, E., Macharis, C., Vereecken, L. and Woxenius, J. (2003), "Is intermodal freight transport more environmentally friendly than all-road freight transport? A review", *NECTAR Conference No. 7, Umeå, June 13-15*.
- Krygsman, S., Dijst, M. and Arentze, T. (2004), "Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio", *Transport Policy*, Vol. 11 No. 3, pp. 265-275.
- Lindholm, M. (2010), "A sustainable perspective on urban freight transport: factors affecting local authorities in the planning procedures", *Procedia Social and Behavioral Sciences*, Vol. 2 No. 3, pp. 6205-6216.
- Lumsden, K. (2011), *Economy of Transportation Systems*, Chalmers University of Technology, Gothenburg.
- Lund, H. and Clark, W.W. (2008), "Sustainable energy and transportation systems introduction and overview", *Utilities Policy*, Vol. 16 No. 2, pp. 59-62.
- Macario, R. and Marques, C.F. (2008), "Transferability of sustainable urban mobility measures", *Research in Transportation Economics*, Vol. 22 No. 1, pp. 146-156.

- National Pollutant Inventory (2013), "Latest NPI emission data 2012-2013", available at: [www.npi.gov.au/npi-data/latest-data](http://www.npi.gov.au/npi-data/latest-data) (accessed November 15, 2014).
- Piel, W.J. (2001), "Transportation fuels of the future?", *Journal of Fuel Processing Technology*, Vol. 71, pp. 167-179.
- Plakhotnik, V.N., Onyshchenko, J.V. and Yaryshkina, L.A. (2005), "The environmental impacts of railway transportation in the Ukraine", *Transportation Research Part D*, Vol. 10 No. 3, pp. 263-268.
- Qureshi, I.A. and Huapu, L. (2007), "Urban transport and sustainable transport strategies: a case study of Karachi, Pakistan", *Tsinghua Science and Technology* Vol. 12 No. 3, pp. 309-317.
- Reinhardt, G.A. and Falkenstein, E.V. (2011), "Environmental assessment of biofuels for transport and the aspects of land use competition", *Biomass and Bioenergy*, Vol. 35 No. 6, pp. 2315-2322.
- Richardson, B.C. (2005), "Sustainable transport: analysis frameworks", *Journal of Transport Geography*, Vol. 13 No. 1, pp. 29-39.
- Rodrigue, J.-P., Comtois, C. and Slack, B. (2013), *The Geography of Transport Systems*, Routledge, Taylor and Francis Group, New York, NY.
- Rondinelli, D. and Berry, M. (2000), "Multimodal transportation, logistics, and the environment: managing interactions in a global economy", *European Management Journal*, Vol. 18 No. 4, pp. 398-410.
- Sandvik, E.T. (2005), *Environmental Impacts of Intermodal Freight Transport*, Molde University College, Molde.
- Santos, G., Behrendt, H., Maconi, L., Shirvani, T. and Teytelboym, A. (2010), "Part I: externalities and economic policies in road transport", *Research in Transportation Economics*, Vol. 28 No. 1, pp. 2-45.
- Schijndel, W.J.V. and Dinwoodie, J. (2000), "Congestion and multimodal transport: a survey of cargo transport operators in the Netherlands", *Transport Policy*, Vol. 7 No. 4, pp. 231-241.
- SCOTI (2012), "National land freight strategy: a place for freight", Standing Committee on Transport and Infrastructure (SCOTI), Commonwealth of Australia, Canberra.
- Seiffert, M.E.B. and Loch, C. (2005), "Systemic thinking in environmental management: support for sustainable development", *Journal of Cleaner Production*, Vol. 13 No. 12, pp. 1197-1202.
- Seuring, S. and Müller, M. (2008), "From a literature review to a conceptual framework for sustainable supply chain management", *Journal of Cleaner Production*, Vol. 16 No. 15, pp. 1699-1710.
- Shrestha, R.M., Anandarajah, G., Adhikari, S., Jiang, K. and Songli, Z. (2005), "Energy and environmental implications of NO<sub>x</sub> emission reduction from the transport sector of Beijing: a least-cost planning analysis", *Transportation Research Part D*, Vol. 10 No. 1, pp. 1-11.
- Spielman, M., Haan, P.D. and Scholz, R.W. (2008), "Environmentals rebound effects of high-speed transport technologies: a case study of climate change rebound effects of a future underground maglev train system", *Journal of Cleaner Production*, Vol. 16, pp. 1388-1398.
- Steg, L. and Gifford, R. (2005), "Sustainable transportation and quality of life", *Journal of Transport Geography*, Vol. 13 No. 1, pp. 59-69.
- Stelling, P. (2014), "Policy instruments for reducing CO<sub>2</sub>-emissions from the Swedish freight transport sector", *Research in Transportation Business & Management*, Vol. 12, pp. 47-54.
- Stepp, M.D., Winebrake, J.J., Hawker, J.S. and Skerlos, S.J. (2009), "Greenhouse gas mitigation policies and the transportation sector: the role of feedback effects on policy effectiveness", *Journal of Energy Policy*, Vol. 37 No. 7, pp. 2774-2787.

Tapiador, F.J., Burckhart, K. and Marti-Henneberg, J. (2009), "Characterizing European high speed train stations using intermodal time and entropy metrics", *Transportation Research Part A*, Vol. 43 No. 2, pp. 197-208.

Tegart, G. and Jolley, A. (2001), "Sustainable transport for Asia-Pacific megacities", *The Journal of Futures Studies, Strategic Thinking and Policy*, Vol. 3 No. 5, pp. 419-427.

Thynell, M., Mohan, D. and Tiwari, G. (2010), "Sustainable transport and the modernisation of urban transport in Delhi and Stockholm", *Journal of Cities*, Vol. 27, pp. 421-429.

Velazquez, L.E., Esquer, J., Munguiá, N.E. and Moure-Eraso, R. (2011), "Sustainable learning organizations", *The Learning Organization*, Vol. 18 No. 1, pp. 36-44.

Vergragt, P.J. and Brown, H.S. (2007), "Sustainable mobility: from technological innovation to societal learning", *Journal of Cleaner Production*, Vol. 15 Nos 11-12, pp. 1104-1115.

Western Australian Planning Commission (2009), *Road and Rail Noise and Freight Considerations in Land Use Planning*, Government Gazette, Perth, Western, available at: [www.planning.wa.gov.au/dop\\_pub\\_pdf/SPP\\_5\\_4.pdf](http://www.planning.wa.gov.au/dop_pub_pdf/SPP_5_4.pdf) (accessed February 2015).

Yim, K.K.W., Wong, S.C., Chen, A., Wong, C.K. and Lam, W.H.K. (2011), "A reliability-based land use and transportation optimization model", *Transportation Research Part C*, Vol. 19 No. 2, pp. 351-362.

Zhu, Q. and Sarkis, J. (2004), "Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises", *Journal of Operations Management*, Vol. 22 No. 3, pp. 265-289.

**Appendix. Questionnaire**

**Field of Work:**

- ☐ Logistics and transport service provider                      ☐ Logistics and transport user  
☐ Others, Please Specify .....

**Position:**

- ☐ Consultant                      ☐ Operations manager                      ☐ Supply chain/logistics manager  
☐ Transport/logistics analyst                      ☐ Others, Please Specify .....

**Duration of job experience:** ..... years

**What mode of transport is mostly used/provided by your company?**

- ☐ Road                      ☐ Rail                      ☐ Air                      ☐ Water

A. Please rate the following environmental and social impacts of logistics and transportation activities in your company:

Socio-  
environmental  
performance

849

	Very high	High	Medium	Low	Very low
1. Air pollution in terminals	O	O	O	O	O
2. Air pollution along transport path	O	O	O	O	O
3. Fuel additives (e.g. lead which is added to some types of fuel)	O	O	O	O	O
4. Resource and energy consumptions in transport terminals	O	O	O	O	O
5. Required resource and energy in mobility	O	O	O	O	O
6. Resource and energy consumption for distribution network of resource and energy	O	O	O	O	O
7. Resource and energy consumptions in infrastructures construction	O	O	O	O	O
8. Surface water contamination in mobility	O	O	O	O	O
9. Soil contamination in mobility	O	O	O	O	O
10. Surface water contamination in terminals	O	O	O	O	O
11. Soil contamination in terminals	O	O	O	O	O
12. Solid waste of fuel producers	O	O	O	O	O
13. Solid waste of transportation, loading and unloading operations	O	O	O	O	O
14. Noise in transport terminals	O	O	O	O	O
15. Noise and vibration in mobility	O	O	O	O	O
16. Occupied land for transport purposes	O	O	O	O	O
17. Changes in eco-system of land	O	O	O	O	O
18. Hazards and incidents in mobility	O	O	O	O	O
19. Hazards and incidents in terminals (e.g. while loading, unloading, etc.)	O	O	O	O	O
20. Congestion in terminals	O	O	O	O	O
21. Congestion in legs of transport	O	O	O	O	O
22. Delay because of congestion	O	O	O	O	O
23. Disturbing Public health as a result of air pollution, injuries in incidents for operators	O	O	O	O	O
24. Disturbing Public health as a result of air pollution, injuries in incidents for users	O	O	O	O	O
25. Disturbing Visual enjoyment in vicinity of terminals and transport routes	O	O	O	O	O
26. Disturbing Fair use of services and opportunities of transport for users	O	O	O	O	O
27. Unavailability of different transport modes for users	O	O	O	O	O
28. Unavailability of transport services in terms of time	O	O	O	O	O
29. Unaffordability for users	O	O	O	O	O
30. Unreliability of transport as a result of potential delays and damages	O	O	O	O	O
31. Lack of Equipment safety for operators in terminals	O	O	O	O	O
32. Lack of transport safety for operators	O	O	O	O	O
33. Not being convenience and easy to use for users	O	O	O	O	O

Table AI.



MEQ  
26,6

B. Please indicate the status of your company regarding the following strategies (1 = Not in the company’s strategy, 2 = In planning process, 3 = Planned but not implemented, 4 = Planned and in the beginning of the implementation, 5 = Planned and implemented).

850

	5	4	3	2	1
34. Consuming more environmental friendly fuels and energy resources	O	O	O	O	O
35. Using fuel-efficient vehicles	O	O	O	O	O
36. Using high capacity vehicles (e.g. road trains and multiple container trucks)	O	O	O	O	O
37. Employing advanced ICT-based transport management systems	O	O	O	O	O
38. Improving e-services and e-commerce to replace unnecessary travels	O	O	O	O	O
39. Providing transport users with information on environmental impacts	O	O	O	O	O
40. Motivating users to change their lifestyles and transport habits	O	O	O	O	O
41. Vehicle sharing between different companies, departments and users	O	O	O	O	O

Table AII.

C. How much your company has been influenced by the following governmental policies?

	Very high	High	Medium	Low	Very low
42. Management and investment in public transport services	O	O	O	O	O
43. Introducing carbon tax and other similar legislations	O	O	O	O	O
44. Introducing incentive systems for more environmental friendly operations	O	O	O	O	O
45. Land-use optimization (e.g. roads and terminals design)	O	O	O	O	O
46. Spatial planning	O	O	O	O	O
47. Constructing higher occupancy vehicle lanes	O	O	O	O	O
48. Improving road characteristics and conditions	O	O	O	O	O

Table AIII.

**About the authors**

Mohammadreza Amiri Khorheh is a PhD Candidate at the University of Notre Dame, Australia. He is specialized in operations management and information systems. After receiving his Master Degree in logistics management from the University of Borås, Sweden, he expanded his research and professional work to more logistics and transportation-oriented subjects. He has worked as a Business Analyst and an IT Manager in different industries. His current research and professional focus is on logistics cost optimization in retail industry. Mohammadreza Amiri Khorheh is the corresponding author and can be contacted at: [amiri@khorheh.com](mailto:amiri@khorheh.com)

Dr Frank Moisiadis is the Head of Mathematics and a Senior Lecturer at the University of Notre Dame, Sydney. Frank has a PhD in software engineering (thesis on prioritization algorithms for system requirements using fuzzy graphical rating scales, a MSc in Computer Science (thesis on improving search algorithms and path planning for autonomous robots) and a BSc (Hons) in mathematics. His current research focusses on using fuzzy graphical rating scales for requirements engineering, mathematical modeling for transportation systems, optimizing information flows in health systems and optimizing random mutations for evolutionary algorithms. He has authored over 30 international and national research papers, supervised

---

PhD students in artificial intelligence, health informatics, information systems and software engineering and authored two editions of the textbook, "Principles of Information Systems" published by Cengage Learning (2007 and 2010).

Dr Hoda Davarzani is an Adjunct Lecturer at the University of Sydney. She received her PhD of industrial engineering from the Faculty of Engineering at the Tarbiat Modares University, her MSc from the same university in the Industrial Engineering and her BSc in industrial engineering from the Bu-Ali-Sina University. After two years of post-doctoral research program at the Lund University, Sweden, she joined the University of Technology Sydney and the University of Notre Dame as a part-time Lecturer. She is currently working as an Adjunct Lecturer at the University of Sydney. Her main areas of research interest include purchasing contracts, uncertainty in supply chain management, disruption management and sourcing strategies. She more than 30 research papers published in international journals and conference proceedings. She is currently acting as Reviewer for several international journals including *International Journal of Production Research*, *Annals of Operations Research* and *International Journal of Production Economics*.