Chapter 4
Technology Innovations in Green Transport

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Abstract The paper uses the case study of Limpopo province to discuss technology innovations in green transport in South Africa with respect to the reduction of global greenhouse emission through technology innovation. South Africa's emission from fuel combustion is the world's 15th largest in forms of CO emission because it contributes about 1.2% of global emissions. In a submission from the Department of Environmental Affairs (DEA) on the impact of greenhouse emissions stated that companies are required to be innovative to reduce the carbon emission levels in South Africa. Literature on road transport in South Africa shows that road transport is the fastest growing source of greenhouse gas emissions, accounting for 19% of global energy consumption. The policy to promote an integrated public transport in municipalities is in line with the National Development Plan and the White Paper on National Climate Change Response. This requires innovative technology that promotes carbon trading markets such as taxi recapitalisation programmes and carbon tax on new vehicles. The study analysed the factors influencing green technology innovations in South Africa with specific reference to Limpopo province green transportation study. The methodology used to unpack innovative technology in South Africa discusses green technology in Limpopo province in the context of greenhouse gases emission reduction innovative technologies in the transport sector with respect to sustainable fuels, energy efficient systems and smart information as well as hybrid technologies. The study advances arguments on technologies for engine and propulsion systems, alternative energy sources, navigation technologies, cargo handling systems, heating and cooling vehicles, road and rail vehicles and maritime transportation with respect to innovations as well as battery charging systems, engine oil disposal etc. The findings shows that no single trajectory of technology innovation in green transport will suffice but technological innovations that improve fuel economy and transition from fossil fuels to cleaner fuel alternatives. The study in Limpopo province showed that green transport innovations must not obscure the role of non-technological innovations in reducing emissions, but the two should be tackled with green transport value chain as a whole.

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4.1 Introduction

Reducing Greenhouse Gas (GHG) emission from the transport sector in South Africa should be a matter of priority considering that most major role players in the transport manufacturing industry are committed to shifting to new innovative technologies such as electric cars or hybrid vehicles. The issue of technology innovation in South Africa has to be addressed from a holistic approach across the value chain in addition to tax policies to reduce greenhouse emission in the transport industry. In rural provinces, such as Limpopo the participation of traffic officers, bus and taxi drivers, car repairers, and manufacturers would be primordial (Lin and Ho 2010). The paper uses examples from Limpopo province to argue that technological innovations that improve fuel economy and the transformation of the energy bases of the transport sector are essentials for GHS abatement. However, these innovations must consider the value chain in the transport industry including non-technological innovations such as green transport logistics display of information for commuters. The technology innovations should include less visible innovations such as mass transit, access cards, radio information, and treatment of used engine oils at appropriate recycling sites. The paper argues that although innovation will play an important role in the transportation sector in South Africa in the future, at the grass root level, three concepts can be said to influence technology innovation in green transport i.e. management skills, organisational enforcement and awareness support for innovative ideas. According to Vigar (2000), the definition of technology innovation in the transport industry has been narrowed down to green transport technology. Technological innovations in the transport industry has been narrowly defined and such narrow definition can limit for example innovations in traffic management or smart transport logistics and non-technological innovations that reduce emissions related to road transport. The data that streamlines the definition were collected from the case study areas in Limpopo province and from the literature review. The survey followed the administration of questionnaires to 120 people in the transport industry including vehicle engine repairers, fuel dealers, car heating and cooling technicians, taxi and bus drivers, car electricians, private car owners, traffic officers and commuters. A desktop review of relevant literature on sustainable transport and innovation was undertaken. The paper unpacks green transport technology innovation with respect to Limpopo province because of the significance of road transport in greenhouse emissions in the province. This was unpacked with respect to the awareness on issues which can have a particular pollutant influence on air quality. The Limpopo case study demonstrates the experience of many rural dwellers who depend on the current form of motor vehicle technology to commute, but the current technology and vehicle use increases the emission of CO_2, NO_x, CO and VOC (Litman and Burwell 2006).

4.2 Literature Review

According to a report by the OECD (2005), technology innovation is defined as the introduction of technologically new or substantial changes in goods or services or the use of a technologically new or substantially changed process (Chapman and Quin 2003). This definition dates back to the beginning of the 1990's and it was inspired by sustainable transport system researchers. This concept is widely explored by Nijkamp (1994), Vigar (2000), Friedl and Steininger (2002) where they argue that there are three kinds of innovations i.e. non-technical innovations product and process innovations. Their emphasis was on the role of technological, organisational and environmental issues that help to create a social support to accompany the establishment of more ecological modes of transport with reduced GHG (Sviden 1988). Sahal (1980) however, argues that innovation in the transport sector is not only a productive activity that requires technological innovation but also an innovative technology that puts emphasis on the health of commuters. These views means that the concept of the green transport should reduce per-capital kilometer travelled in general (Miles 2005). In other words the transport sector is within the sphere of the entrepreneur and the customer and both require technological innovations to keep up with the information age and the reduction in greenhouse emissions. According to Burneister and Djellal (2004) the debate on transport service innovations started in the 1960s when innovation emerged as an area of research with respect to mainly car manufacturing. However, Schot and Geels (2008) and Swann (2009) argue that innovative theory refers to products, process, market inputs and organisational innovations. In other words, technology innovation in a green transport economy cuts across the value chain in the transport industry. With respect to the concept it can be said to include technological process innovations and organisational process innovations. The OECD (2005) defines the concept of innovation in the transport sector in the context of basic access of individuals, group interest in the transport industry as related to safety, health standards, and emission control affordable transport, access to different modes of transport in a competitive economy (Schmookler 1966).

Functional Trajectories of Innovations in Green Transport

The literature review on technology innovation shows that there are three main areas innovations can be classified, i.e. non-technical, technological product innovation process, organisational and environmental innovations. Although the survey from Limpopo province dealt with mainly innovations from road transport, other forms of innovations were discussed. The study looks at innovations that deals with the material function of the vehicle service (the car) and innovations that involves the function of treatment of information, communication and innovations that deals with organisational or relational functions. The advantage of the three categories is that it allows us to determine innovations in the transport sector from both goods and services within the value chain (Sahal 1980). The three categories can be broken down further into five functions as follows:

Technology Innovation Functions

These are innovations that involve the material substance of the vehicular product such as the body parts of the vehicles and the flow of information (Rennings 2000). The study in Limpopo province shows that for innovative light car materials, 62% of the respondents indicated that they preferred steel body parts because they are durable. In terms of information flow, 41% of the respondents indicated that the introduction of the BRT in Polokwane will enhance access to information with respect to the system. With respect to drivers and passengers, smart ticketing system, 57% indicated that in rural areas it will be difficult to implement because of the educational level of most commuters and low paying jobs which may not be enough to purchase hybrid vehicles (Aquila-Obra and Melendez 2006).

Organizational Innovation Functions

These are innovations that involve the flow of information and dealings from one service to the other within the transport sector value chain. Innovations that deal with methodological functions i.e., new approaches to provide a service for example, government support services are important for technology and logistics. When the respondents were asked to indicate their preferences to transport sector information, 87% indicated they got to know about the green transport concept from newspapers, the internet, and very little from the government. However, on taxi re-capitalization and information on the BRT 87% indicated they were well informed of government policies through the internet, the television, newspapers etc. 92% indicated that there is lack of awareness campaigns on the green transport concept in the province (Aronsson and Brodin 2006).

Environmental Innovation Function

These are innovations that deal with how external environmental factors influence the release of GHG in the air. Emissions is one of the major causes of air pollution and with respect to this (Azevedo et al 2007), indicated that customer pressure such as demand for new vehicle can trigger regulations and policy innovations to resolve environmental related issues (Lin 2007). From the study in Limpopo province, innovations that can contain the pollution of the environment such as smoke from car exhausts, can be reduced by providing policies that promote de-registration of vehicles that pollute the environment. However, 37% of the respondents were not in favour because, according to them it will be tantamount to de-registering most vehicles older than 10 years, (Aronsson and Brodin 2006).

Hybrid Vehicles

The Toyota Prius, the world's most popular hybrid car, uses a combination of an internal combustion engine and a battery electric drive system to increase fuel economy and reduce emissions. When pulling away from a stop, the electric motor powers the car, drawing on the battery for power. At the Paris worlds motor show which took place from 1st to 6th October 1–6, 2018, a hybrid car was claimed to have been charged and would travel 200 km. The electric storage and charging

technology that made this possible was powered by solar panels. The technology is said to be easily deployable at existing or future road and highway stations, as solar energy continues to develop throughout worldwide. It was indicated that it is the charging solution that will eventually enable electric cars to rival traditional combustion-powered vehicles, whose growth was made possible by gas stations. The team that developed the technology is based in France, but the development potential for this technology is clearly international (Coqueline energies 2018).

4.3 Methodology

The methodology used to discuss technology innovation in Limpopo Province was based on (Nelson and Winter 1982) method of first defining the problem before unpacking the content. To achieve this, a literature review (Sect. 4.2) of current research and publications on technology innovations in the transport industry was undertaken to put the subject in context. This was followed by the identification of key informants who attended a workshop on green transport economy in Polokwane. Among them were taxi associations' representatives, bus and taxi drivers, traffic officers, auto electricians, motor electricians, pedestrians, car dealers, rail, air and commuters in general. A total of 120 relevant stakeholders in the transport industry were interviewed to give their views on technological innovations in Limpopo Province. In addition to this, close and open-ended questionnaires were administered to them. The analysis of the survey results was mainly on how the transport industry main stakeholder's current views on the concept of innovation in green transport. In addition to the analysis, also discussed were type of skills that will be required when new innovations are introduced in the transport industry.

4.4 Discussions

The expression technological innovation emerged from the work of Dosi (1982), Dosi (1984) and Schumpeter (1983) who postulated that innovation is a process of learning which is localised but can be expanded to other sectors and regions (Kimberly and Evanisko 1981). The central theme of the discussion in Limpopo Province was to get the opinions of stakeholders in the transport sector with the aim of informing policy makers on the potentials of technology innovations in the transport industry, particularly at the grass root level (Azevodo et al. 2007). In view of the fact that road transport has a significant impact on environmental problems, most of the innovations pointed out by the respondents were with respect to pollutant impact on air quality particularly the concentration of:

- CO_2—Carbon Dioxide;
- NO_x—Nitrogen Oxide; and

- VOC—Volatile Organic Compound.

In order to determine the views of the respondents on vehicle emissions a survey was undertaken with respect to non-technical and technical innovations and the restrictions of emissions components. They were required to respond to a number of questions on emission control in the province. The perceptions of the respondents were with respect to technical and non-technical innovations in Limpopo province, (Alexe and Ezhilarasie 2011). They were asked to indicate their choice of selected transport sector value areas by indicating on a scale 0–5 with 0 being; do not agree, 1-fairly agree, 2-agree, 3- highly agree, 4-very highly agree, and 5- totally agree as shown in Table 4.1.

Table 4.1 is a compilation of 120 respondent's choice of technical and non-technical innovation categories relevant to green transport in Limpopo province. Note that the classification was to determine what the stakeholder and respondents considered technical and non-technical innovations with respect to the transport industry. In each column of the technical innovations, 120 respondents gave a rating of 0 to 5. In each column the total highest score would be theoretically 9000 i.e. $5 \times 120 \times 15$ selected transport sector value chain areas and the lowest would be theoretically 0. The total highest score was 44 or 7.33% as compared to non-technical with an average of 26 or 3.60% and material information innovation, 23 or 2.8%, communication innovation, with 43 or 7.2% respectively (ITF 2010). The field survey showed that apart from stakeholders such as traffic officers, auto electricians, auto mechanic and car dealers who had a fairly good knowledge of technology innovations in the transport sector value chain, most of the respondents were not aware of the green transport technology innovation concepts (Hamdouch and Samuelides 2001).

Summary of Technical and Non-Technical Transport Innovations in Limpopo Province

Table 4.1 innovations as perceived by the 120 respondents were derived and classified into four categories as shown in Table 4.2.

Table 4.2 shows that innovations with respect to sustainable green transport in Limpopo province would be dependent on new external technologies, new markets, new institutional rules and new forms of information from mainly major car manufacturing countries such as Japan, France, Italy, USA to mention just a few (Foster and Green 1999). Adaptations according to 69% of the respondents depends on the path the local authority follows with respect to training policies to respond to new job skills that would be needed. This would in turn depend on the degree of buy-in, flexibility and attitude of the stakeholders as and when new green transport innovations are introduced (Geels and Green 2004).

Table 4.1 Technological and Non-Technological Innovations

Selected transport sector value areas	Categories of technical innovations rating scale 0–5					
	Technical green transport innovations	Non-Technical green transport innovations	Material information innovations	Internet information innovations	Communication technology innovations	Policy and regulatory innovations
	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average score for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5
Access control i.e. low emission zones	4					3
Mass transit modes of transportation	3		3	5	4	4
Parking management fleet	4				3	5
Intelligent transport system information to users	4		5	4		
Ramp metering actual time and public transport structure	3					4
Fuel use (bio-gas and hybrid vechiles)	4					
Pedestrian/ cycling/roller scatter	5	5	4			4
Park and pay	4	5			5	3
Park and ride	4		4		4	
Car pooling		4			4	4

(continued)

Table 4.1 (continued)

Selected transport sector value areas	Categories of technical innovations rating scale 0–5					
	Technical green transport innovations	Non-Technical green transport innovations	Material information innovations	Internet information innovations	Communication technology innovations	Policy and regulatory innovations
	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average score for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5	Average scores for 120 respondents 0–5
Dial a ride			3		4	4
Flect, freight forward and clearing management and ticketing		4				4
Taxes on fuel use						√a
Data acquisition	4	4		3	5	
Technology to reduce the emission of NOx, CO_2 and VOC on thr environment	5	5	4	5	4	5
Total percentage	44 × 15 = 660/9000 = 7.33%	26 × 15 = 390/9000 = 3.60%	23 × 15 = 345/9000 = 3.80%	21 × 15 = 315/9000 = 3.50%	33 × 15 = 495/9000 = 5.50%	43 × 15 = 645/9000 = 7.20%

Source Authors field data 2016

Table 4.2 Classification of technical and non-technical innovations in Limpopo Province

Category	Innovations
Roads infrastructure	Pedestrian/cycling/roller skater Ramp metering actual time and public transport structures Air and rail Taxes on fuel use
Policy and regulations	Parking management fleet Access control i.e., emission zones Fleet, freight forward and clearing management and ticketing Intelligent transport system information to users Car pooling Dial a ride
Chemicals	Fuel use (bio-gas and hybrid vechiles) Technology to reduce the emission of NOx, $C0_2$ and VO on the environment
Transport cost	Data acquisition Park and ride

Source Authors field data 2016

4.5 Challenges to Technology Innovation in Green Transport in Limpopo Province

The study categorised the challenges to innovation in green transport in Limpopo Province into two:

Technology innovation: This is considered a new concept because of the following reasons:

- It allows basic access and development needs of individuals, companies and society to be met safely in a manner consistent with human and ecosystem health and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode and supports a competitive economy, as well as a balanced regional development.
- Limits emissions and waste within the planets ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable at or below the rates of development of renewable substitutes while minimizing the impact on the use of land and generation of noise.
- Safety and E-administrative systems.

Affordability issues: Affordability was identified by the respondents from rural areas to be one of the fundamental issues to ensure the buy-in for green transport technologies such as hybrid electric cars, bio-gas fuel etc. However, the study showed that the introduction of public transport systems such as the Bus Rapid Transport Systems can be one of the fastest ways to begin the introduction of new technologies in the transport sector (Kemp and Rotmans 2004).

Recommendations

In view of the analysis discussed above, recommendations to address the issues are outlined into short and medium term and long term as follows:

Short and Medium Term Recommendations

The short term recommendations emphasis issues that can be tackled within a period of ten years.

- Awareness campaign: to introduce and explain the green transport concept to the public.
- Framework to encourage metropolitan areas and municipalities to embark on BRT projects, which should incorporate some type of the new technologies discussed.
- Framework to integrate land use planning with dedicated lanes for non-motorised transport, BRT and cycling routes and pedestrian walk ways.
- Introduce green concept curriculum in secondary schools to sensitize them at an early age on the future of green transport economy.
- Provide collection site for the collection and recycling of used moto engine oils, and
- Provide incentives to interested companies to pilot green transport technologies.

Long Term Recommendations

The study has shown that long term strategies require more research and planning to bring on board the following recommendations, (DME 2012).

- Fund research institutions and R&D companies to embark on green transport research and technologies and prioritize policy recommendations.
- Establish green transport curriculum development forums to begin to discuss the contents of the curriculum.
- Encourage investment in bio-fuel and solar energy related vehicles.
- Identify long term key skills required for green transport development suitable for South Africa.
- Provide incentives for investors to establish electric vehicle battery stations so that the general public can have access, and
- Ensure buy-in of the green transport concept by engaging with key stakeholder such as private public bus owners and taxi associations on conversion to cleaner fuel products.

Key Role Players Recommended

The key role players identified during the study in Limpopo province but not exhaustive are outlined as follows:

- Taxi Associations
- Department of Transport (DOT)
- Transport Education and Training Authority (TETA)
- Municipalities: Land use planning unit

- Research Institutions
- Rail transport (PRASA)
- Roads agency
- Aviation industry
- Car manufactures
- Roads Traffic Department
- Department of Environmental Affairs (DEA)
- Environmental Protection Agency
- Maritime
- Gautrain
- Traffic and road safety officers etc.

4.6 Conclusions

The focus in this chapter was on technical and non-technical innovations to promote sustainable transport. The study shows that both technical and non-technical innovations are relevant concepts that require more in-depth research to address the problems of greenhouse emissions in South Africa and in particular Limpopo Province. It is difficult to assume that green transport innovations can be accepted by the stakeholders without any form of awareness campaign and support from government. The approach should be a bottom up driven process, particularly in rural areas such as Limpopo province. The targeted population in the survey showed that stakeholders will not be committed to innovations without proper awareness campaigns and buy-in considering current pack of vehicles majority of which are more than 10 years old in rural areas. The study showed that technology innovations in the transport sector are inevitable, but there will be challenges such as cost of hybrid cars, retraining in new skills and qualifications across the transport skills sector. However, research and gradual introduction of relevant policies, to support the concept, provision of vehicle charging parks and logistics incentives for non-motorised inventions etc. should be the approach.

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