Transportation Research Part D 32 (2014) 57–69

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Potential for mitigating greenhouse gases through expanding public transport services: A case study for Gauteng Province, South Africa

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ARTICLE INFO

Keywords:
Public transport
Greenhouse gas emissions
Mitigation costs
BRT
Rapid rail
Megacity

ABSTRACT

South Africa's Province of Gauteng is a fast growing megacity region including the cities of Johannesburg and Tshwane. Increasing population and prosperity lead to a steadily growing energy demand and thereby increasing greenhouse gas (GHG) emissions. One third of the province's final energy consumption comes from the transport sector, dominated by motorized individual transport. Due to the limited financial resources to fund public transport initiatives, the most cost-effective means to reach the GHG mitigation targets are intended, without jeopardizing the economic growth. Recently, a bus rapid transit (BRT) system (Rea Vaya) and a rapid rail link (Gautrain) have been introduced to enforce the public transport system. In this paper, we investigate planned and possible future network expansions of the BRT and the Gautrain in terms of transport performance, costs of network expansions and GHG mitigation potential. Based on a trip rate model, we show that extensions of the current network can increase passenger numbers significantly (between 320% and 660% between 2013 and 2040 depending on the framework conditions). However, despite these expansions, the modal share of the BRT and the Gautrain in total passenger-kilometres travelled remains below 4% until 2040. This results in a decrease of cumulated GHG emissions of less than 1% until 2040 and relatively high GHG mitigation costs (4948–30045 ZAR_{2013}/t CO_2e). Nevertheless, a better integration of all public transport systems can increase the attractiveness of the services, which can result in a higher modal shift from private cars and thereby higher GHG emissions reductions at lower costs.

Introduction

South Africa is the largest economy in Africa and has experienced strong economic growth since the end of apartheid in 1994, showing annual growth rates of up to 5.6% (IMF, 2013). Hand in hand with this economic growth goes the need for energy services and an increase in greenhouse gas (GHG) emissions. South African carbon emissions increased from 250 Mt CO_2 in 1990 to about 350 Mt CO_2 in 2010 (IEA, 2013). These figures correspond to per capita emissions of about 7–8 t CO_2/capita, which is a figure comparable to industrialized countries such as the United Kingdom or Germany.

Gauteng Province is the economic centre of South Africa contributing about one third of the national GDP. Growth rates have historically been higher than in the rest of the country (in average about 0.3%/a higher between 1996 and 2008 (StatsSA,

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http://dx.doi.org/10.1016/j.trd.2014.07.002
1361-9209/

2014; GPG, 2013)). GHG emissions allocated to Gauteng were about 127 Mt CO_2e in 2009, of which about 25% can be attributed to transport activity (Tomaschek et al., 2012b). The economic dominance has caused steady migration to the province. Gauteng currently holds more than one fifth of the nation's population, contributing only about 1.4% to the total land area (GCIS, 2011). This trend is forecasted to continue in future, making it possible to double Gauteng's population and increase its GDP by more than 250% (constant prices) between 2010 and 2040 (Wehnert et al., 2011; DPTRW, 2013).

The Province has realized its importance for South Africa and wants to play a leading role for the country's climate protection strategy. The transport sector was proposed as one of the key starting areas. The expansion of the public transport system is seen as one promising option to mitigate GHG emissions (DLGH, 2010). The potential and costs of suitable measures have, however, not yet been evaluated.

The public transport system of Gauteng has historically been mainly built on minibus-taxis as well as on a few scheduled bus and train services. Important expansions were the introduction of a bus rapid transit system (BRT) in Johannesburg (Rea Vaya) in 2009 and a rapid rail system for Gauteng (Gautrain) in 2010. The construction of the Rea Vaya BRT in Johannesburg is divided into different phases and began operation with phase 1A in August 2009 with a trunk route of 25.5 km. In addition, phase 1B (18 km trunk route) started operation in October 2013. The long-term BRT network shall comprise 330 km of trunk routes and provide BRT access to about 80% of Johannesburg's population (DOT, 2009).

The construction of the Gautrain rapid rail system started in September 2006 and the first phase began operation in June 2010, connecting the CBD Johannesburg with the international airport in the east of the Province. A second phase, completed in August 2011, linked Rosebank Station in Johannesburg and Hatfield Station in Pretoria. The current system network is of 80 km length. Future plans outline comprehensive expansions (DPTRW, 2013).

However, a first evaluation shows that the aims of both projects were not achieved in terms of passenger numbers. For example, the Rea Vaya BRT phase 1A was planned with passenger levels of approximately 136000 pass./day (Grütter, 2011). Conversely, the actual passenger numbers reached only 38000 pass./day in February 2012 (Ngcobo, 2012), which corresponds to a level of achievement of about 28%. A similar statement has to be made for the Gautrain, where about 52000 daily passengers trips were performed in October 2013 (Venter, 2013a), whereas an official plan estimated about 108000 pass./day (Venter, 2012b).

To show and to evaluate the likely performance of the future BRT and the rapid rail system in Gauteng and to determine the potential for mitigating greenhouse gases, this paper aims to:

- Estimate the achievable passenger volumes of already planned as well as of possible further phases.
- Assess the mitigation potential for greenhouse gases.
- Evaluate the costs of possible further phases and their GHG mitigation costs.
- Give policy recommendations on how to set future public transport initiatives in order to achieve the overarching political aim of reducing GHG emissions.

All monetary figures in this paper are given in South African rand (ZAR) with the value of the year 2013. The exchange rate is 1 USD_{2013} = 9.5 ZAR_{2013} (FED, 2013). To calculate the net present value of future investments, we use a real discount rate of 8% according to DOE (2011).

Literature review

Providing efficient transport systems is a central issue in fast growing urban areas such as in emerging and developing countries. Furthermore, the reduction of transport-related GHG emissions is a key challenge, which can be reached through various strategies. Nakamura and Hayashi (2013) give an overview of strategies and instruments for low-carbon solutions in urban transport. They find that the effectiveness of different GHG mitigation measures is highly dependent on the development process of the considered city and the types of urban land-use transport systems.

To rank the cost-effectiveness of GHG mitigation measures in the transport sector, GHG mitigation costs can be considered (e.g. Kok et al., 2011; Lutsey and Sperling, 2009; Corbett et al., 2009). Kok et al. (2011) give a review on methodological approaches to evaluate the cost-effectiveness of measures for GHG mitigation in the transport sector. Lutsey and Sperling (2009) use a technology oriented, static, bottom-up approach in order to analyse the greenhouse gas mitigation potential of various technology options for the transport sector of the United States. Furthermore, alternative fuels were part of their analysis. They came to the result that many transport oriented mitigation options are available, which show low or even negative GHG mitigation costs, such as increases of vehicle efficiency through engine optimizations, reduced rolling resistance and aerodynamic improvements. Changes of the modal shift or expansion of the public transport system, however, were not part of their study.

Such expansions represent another measure to reduce transport related GHG emissions aiming at a shift from private to public vehicles, which was inter alia analysed by Stanley et al. (2011). Also, the mitigation costs of an increased public transport share are the subject of different studies (e.g. Dedinec et al., 2013; Wright and Fulton, 2005). Wright and Fulton (2005), for example, examined GHG mitigation costs for the introduction of a BRT system considering the construction costs of network infrastructure. They did, however, not calculate the achievable modal share but assumed a modal share related to the introduction of a BRT assuming a modal split for a fictitious developing-nation city. They postulate that a diverse and