Investment Decision Making for Alternative Fuel Public Transport Buses: The Case of Brisbane Transport

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Abstract

Cleaner and less polluting public transport buses based on alternative fuels are of paramount importance if cities are to attain their ambitious emissions reduction targets. Public transport buses are high usage vehicles that operate in heavily congested areas where air quality improvements and reductions in public exposure to harmful air contaminants are critical. As such, they are good candidates for achieving both near-term and long-term emission reductions. Decision making for the investment in alternative fuel buses is dependent on future technological development and emissions standards, and it is difficult, given the uncertainty in regards to both these factors. The objective of this paper is to develop an analytical framework that will give us more insight into the trends in emissions standards as well as technology development, and eventually translate these insights into a sound investment decision making strategy. This paper concludes that, due to presence of uncertainties, the decision maker (public transport fleet manager) can take only incremental steps that will allow him or her to safeguard investments. Furthermore, if policy makers

are serious about accelerating the diffusion of alternative fuels, they should aim at creating stable policy environment.

Introduction

Cities around the world have set ambitious emissions reduction targets. The primary environmental objective of any city is to reduce human exposure to harmful pollutants while at the same time not hindering the movement of people. This objective can be achieved in two ways—reduce the number of vehicles and reduce the pollution from each vehicle. The number of vehicles can be reduced by improving public transport and simultaneously encouraging residents to use public transport instead of driving their personal automobiles. Pollution from each vehicle can be reduced by promoting the use of alternative fuel vehicles that have lower emissions. Given the potential of alternative fuels as a clean and safe energy resource, they can be expected to play a larger role powering the transport sector in the future. Cleaner and less polluting public transport buses based on alternative fuels are of paramount importance if cities are to attain their ambitious emissions reduction targets, as public transport buses are high usage vehicles that operate in heavily congested areas where air quality improvements and reductions in public exposure to harmful air contaminants are critical. As such, they are good candidates for achieving both near-term and long-term emissions reductions, as many buses are centrally kept and fueled, making the introduction of new technologies and alternative fuels more efficient (Kojima 2001).

This paper establishes the importance of emissions standards and technological development during the decision making process of procurement of new public transport buses. A bus has a life expectancy of about 20 years. If the emissions standards change during the lifespan of a bus and if it can no longer satisfy the requirements, the bus has to be phased out or upgraded to comply with the emissions standards requirements—which cost time and money, thus leading to financial and service losses. The objective of a decision maker while investing is to optimize the returns of his/her investments—low costs for high returns. Given the long life span of the buses, a decision maker is faced with a number of uncertainties while making the investment decision. These uncertainties are related to the progression of the technology development and emissions standards for diesel buses, i.e., the pace at which they will become more stringent and the development of technology over time. Numerous strategies can be employed to face this uncertainty (Walker et al. 2001; Kim and Sanders 2002), including delay of decision, do

further research, implement a flexible solution, implement a robust solution, take incremental steps by implementing a solution that builds on the existing competencies, etc.

This paper focuses on Brisbane Transport as a case study. The aim is to develop an analytical framework that will allow insight into both the trends in emissions standards and technology development, eventually translating these insights into sound investment decision making. First, the paper discusses the types of uncertainties and their impact on the investment decision making strategy. Second, the Brisbane Transport case study is introduced. Third, different alternative fuel technologies for public transport buses and their characteristics are discussed. Fourth, the paper focuses on the trends in emissions standards for public transport buses and how they affect the public transport fleet manager in their procurement strategy. Finally, recommendations are given with respect to the implications for future emissions standards trends and the choice of alternative fuel buses for the fleet by applying this to Brisbane case study.

Impact of uncertainties on investment decision making

The transport sector is capital intensive, and investments are characterized by longevity of technological components and irreversibility due to the large up-front sunk costs. In addition, there are different sources of uncertainty that have an impact on investment decisions, such as the uncertainty about the pace and direction of technological developments and uncertainty about future policy and regulations (Meijer et al. 2007). Technological uncertainty can relate to the technology itself, to the relation between the technology and the technological system, or to the availability of alternative technological solutions (both technologies that are already available as well as technologies that might become available in the future) (Meijer 2008). Furthermore, uncertainty can emerge about current policy (e.g., uncertainty about the interpretation or effect of policy, or uncertainty due to a lack of regulation) or about future changes in policy. Uncertainty about governmental behavior (policies) is also an important cause for political uncertainty (Meijer 2008) and, as such, can have a detrimental impact on the diffusion of new alternative fuel technologies. The decision of any actor to invest in alternative fuel technology buses is highly influenced by governmental policies, which determine the "rules of the game"; if the policies are uncertain, then it sends wrong signals to the decision makers and shows that the government is not serious about transition towards sustainability. There are many rules and regulations affecting the

decision making process, but the most relevant of those that directly affect the investment decision making is emissions standards (Welsh 2007).

Decision making for procurement of new buses is heavily based on the emissions standards, as every new bus should comply with the corresponding emissions standards (AATA 2002; Hao et al. 2006). In case a new bus satisfies the "current most stringent emissions standards," then that bus often is selected (Welsh 2007). What makes the job of the decision maker difficult is the uncertainty regarding future emissions standards, coupled with the fact that many competing alternative fuel technologies are still unproven and their long term impact is yet unknown (WSU 2004). A bus has a life expectancy of about 20 years (Welsh 2007); during its lifespan, if the emissions standards change and the bus can no longer satisfy the requirements, then it has to be phased out or upgraded to comply with the emissions requirements. The objective of a decision maker while investing is to optimize the returns of investments – low costs and lower emissions. The new buses should have to be reliable, efficient, and environmentally-friendly and, at the same time, be cost effective in terms of purchasing price, operation and maintenance in order to optimize the taxpayer's resources. Any decision today could have repercussions for the next 25 years or so as the life cycle of a regular bus constitutes 20 years in addition to a lag time of about 4 to 5 years for the process of order and delivery.

In this paper, although we consider that the decision maker is a public transport fleet manager, at the same time we are aware that these decisions are influenced by many political players, a characteristic of every public sector governance environment. Decisions to invest in alternative fuel technology are politically sensitive and influenced by strategic and political reasons (Wüstenhagen et al. 2007). The analytical framework we propose in this paper has the ability to take into account factors such as political sensitivity and other external inputs that affects the decision making process; however, to keep this discussion and our recommendations crisp, we focus only on emissions standards and technological developments. The aim of the framework is to show that investment decision making is impacted by both social and technical components. The public transport sector is a socio-technical system (STS), as it combines social and technical components that interact and function together (Ottens et al. 2006). Social components include actors, rules, regulations, etc; technical components include machinery, buses, etc. An analysis of such systems cannot focus only on technological components; equal relevance should be given to social components (Weijnen et al. 2008; Bauer and

Herder 2009). It is the interaction between these components that determine the direction of system development.

Analytical Framework

We use the socio-technical systems perspective to analyze the problem of investment decision making; such perspective allows the collective analysis of the social and technical components. Our analytical framework as described below is developed to capture the interactions within the transport sector. The framework analyzes *technology, actors* and *rules*—*technology* refers to the physical network such as machinery, buses, engines, etc; *actors* refer to the presence of the multi-actor network; and *rules* refer to regulations and standards. Rules can be classified as formal and informal rules. Formal rules include operational standards (interoperability, process), technical standards (engineering practices), organizational standards (management styles), environmental standards (such as emission limit values), etc. Informal rules include norms, cultures, traditions, etc. Rules are not mere constructs but part of the system; standards co-evolve during the development of the socio-technical systems, and they change or are changed as system functionalities are modified. As shown in the Figure 1, the analytical framework accentuates the interactions within the various components of an STS. For example, *actors* create *rules* and, at the same time, the behavior of the *actors* is more or less governed by *rules*; technology development is constrained by the prevailing system of *rules*, and *rules* are shaped by the current *technology* status; and, finally, *actors* create and manage *technology* and, at the same time, *technology* influences *actor* behavior.

All the three components of a socio-technical system are interdependent; actors, rules and technology interact with each other for the proper functioning of an STS. This implies that the actors' decision making is influenced by both the rules and the technology. As discussed earlier, the aim of this paper is to provide recommendations to the decision maker while investing in alternative fuel technology buses. To gather insight into this decision making process, we apply our analytical framework to a case study, Brisbane Transport.
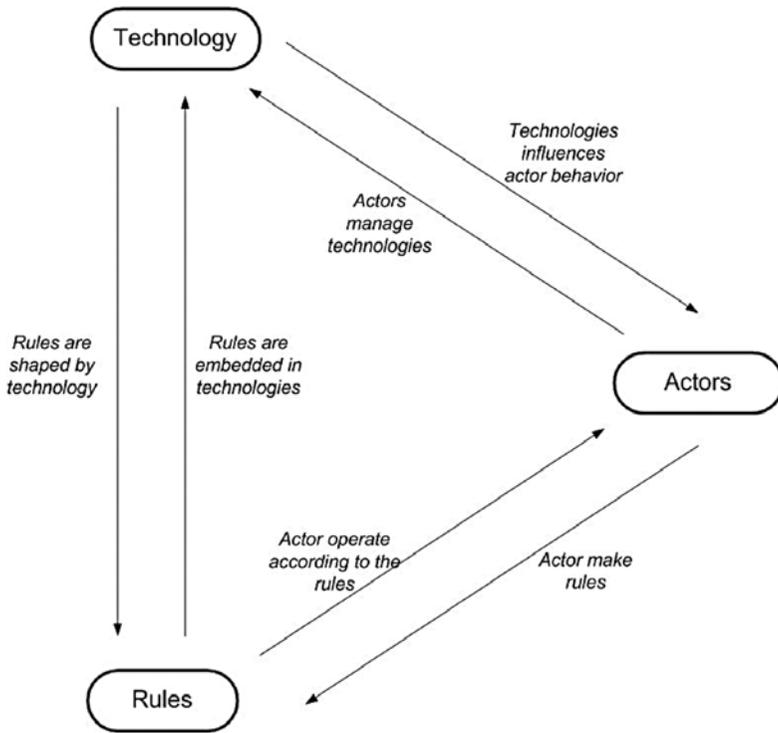
Figure 1. Interactions within a Socio-Technical System

Brisbane Transport case study

The Brisbane City Council predicts huge population growth in Brisbane, especially in the suburbs. With population growth comes more traffic, more vehicles, more emissions; hence, the Brisbane City Council in its *Living in Brisbane 2026—Vision for Brisbane* and *Climate Change and Energy Taskforce—A Call for Action* documents identified safe, reliable and clean public transport as a means to keep Brisbane's air clean and reduce green house gas emissions to counteract the impacts of climate change (Brisbane-Council 2006).

Brisbane Transport is a business unit of the Brisbane City Council, operating suburban and urban bus services in the Brisbane metro area. The current Brisbane transport fleet is 1053 buses (as of Jan 2010) (www.brisbanetransport.info/fleetlist.php). The fleet has a balance of CNG (compressed natural gas) and diesel buses (ratio 60:40). Since the year 2000, only CNG buses have joined the fleet. In line with the

above mentioned *2026 Vision* documents, Brisbane Transport has formulated two strategies to achieve the 2026 vision for Brisbane: increase bus patronage from the existing 67 million to 110 million and add cleaner (i.e., lower emissions) buses to the fleet. Brisbane Transport has estimated that a fleet of 1,785 buses will allow it to reach its 2026 patronage targets (Brisbane-Council 2007). About 85 new buses should join the fleet every year in order to have 1,785 buses in 2026. This number accounts for the older buses that will be withdrawn after 20 years of service life. Hence, about 1,500 new buses will be joining the fleet from 2010 until 2026.

Overview of alternative fuel technologies for buses

There are numerous alternative fuel technologies for public transport buses available in the market; most notable are clean diesel buses, compressed natural gas (CNG) buses, hythane buses, hybrid buses and fuel cell buses powered by pure hydrogen (AATA 2002; WSU 2004). In this section, we discuss, compare and contrast these technologies.

Clean Diesel Buses

There have been tremendous innovations in diesel engine technology over the past few years—for example, advanced engine electronic combustion control, fuel injection systems and turbochargers to optimize performance and lower the emissions (Gifford 2003). Advanced low-sulphur fuels are available in the market. These cleaner diesel fuels produce lower emissions and enable advanced emissions treatment systems (catalysts and filters). Lower amount of sulphur in diesel fuel enables catalytic converters to be used, which, in turn, lower carbon monoxide (CO), nitrogen oxide (NOx) and hydrocarbon (HC) emissions. Emissions treatment such as particulate filters and oxidation catalysts reduce emissions of ozone-forming compounds (NOx and HC) and trap and eliminate particulate matter (PM) (Gifford 2003; Kassel and Bailey 2004). Currently, diesel emissions are reduced by turbo-charging, after-cooling, high pressure fuel injection, retarding injection timing and optimizing combustion chamber design. Turbochargers reduce both NOx and PM emissions by approximately 33 percent when compared to naturally-aspirated engines. Combustion chamber improvements and air-fuel injection advancements are ongoing in the industry and result in improved fuel economy and emission reductions (WSU 2004). As diesel engine improvements have already reached their limit, NOx and PM emission control requires after-treatment devices to satisfy new, stringent emissions standards.

CNG Buses

Natural gas (NG) has been proposed as a much cleaner alternative to conventional diesel. Consisting primarily of methane and other light hydrocarbons, natural gas does not contain hydrocarbons that form harmful emissions. In fact, the principal source of particulate emissions from natural gas vehicles is the combustion of lubricant. Replacing heavy-duty diesel vehicles with CNG equivalents is one option for reducing vehicular particulate emissions dramatically (DOE 2002; Tzeng et al. 2005). Many cities have started investing in CNG buses. For example, cities such as Mumbai and Delhi have completely shifted their fleet from diesel buses to CNG buses (Yedla and Shrestha 2003); for cities in developing countries such as India, CNG buses offers low emissions and cost-effective public transport.

Hythane Buses

CNG buses are looked upon as a potential alternative to diesel buses – they are less polluting and the fuel is widely available. However, in an effort to reduce their pollutants further, CNG buses can be converted to run on hythane (Bauer and Forest 2001). Mixtures of hydrogen and natural gas are considered viable alternative fuels to lower overall pollutant emissions but suffer from problems associated with on-board storage of hydrogen, resulting in limited vehicle range (Nagalingam et al. 1983; Karim et al. 1996). Hythane, a patented product, is a mixture of 20 percent by volume of H_2 and 80 percent methane (Hythane 2007). The laboratory for Transport Technology at University of Gent in Belgium has done considerable research on the suitability of hythane for public transport buses. In its experiment, a city bus with an adapted MAN CNG engine was tested on a chassis dynamometer at four speeds (30, 50, 70 and 80 km/h) with natural gas and hythane (HydroThane 2004). The same load conditions at the same speed were realized for the two fuels so that exhaust emissions concentrations can be compared. The averages over the four speeds of the exhaust gas concentrations with hythane as a fuel compared to natural gas are 66 percent reduction of unburned hydrocarbons (HC), 32 percent reduction of nitrogen oxides (NOx), 17 percent reduction of carbon monoxide (CO), and 13 percent reduction of carbon dioxide (CO_2). Experiments at the University of Lund and City of Malmo gave similar results for hythane (Ridell 2005). There are many cities in the world that are experimenting with hythane, such as the Beijing Hythane Bus Project, whose demonstration phase will be to adapt 30 natural gas engines for hythane operation (Ortenzi et al. 2007).

Hybrid Buses

An emerging alternative to conventional diesel engines is electric hybrid bus technology. Hybrid buses typically use an electric drive coupled in series or operating in parallel with a combustion engine and traction battery. Hybrid technology allows the use of a smaller internal combustion engine that is designed to operate near its optimum efficiency, thereby minimizing engine emissions and maximizing fuel economy. Typically, a hybrid system also employs regenerative braking, which transforms kinetic energy into electric energy, again improving fuel economy. To a fleet operator, hybrid technology is attractive because it does not require the development of new refueling infrastructure or modifications to existing maintenance areas (WSU 2004; Tzeng et al. 2005).

Fuel Cell Buses

Fuel cell buses run on hydrogen, which can be stored on board in high pressure cylinders or could be produced on board through natural gas or methanol. There are many cities in the world currently experimenting with fuel cell buses; for example, the Clean Urban Transport for Europe (CUTE) is a European Union project that saw the development and testing of 27 hydrogen fuel cell buses, three in each of nine cities in Europe (CUTE). This technology is still in its experimental phase; it will be few years before it is commercialized. The main advantage of using fuel cell buses is zero tailpipe emissions, but there are many drawbacks. Obtaining hydrogen fuel is difficult, as hydrogen does not exist in free form in nature. Hydrogen has to be produced from either natural gas or electrolysis that makes it an expensive fuel. Bus prices are currently exorbitant compared to other alternative fuel buses, thus putting this technology out of reach of many public transport authorities (Tzeng et al. 2005).

Table 1 summarizes the comparative assessment of different alternative fuel technologies. The criteria for analysis is maturity of technology, cost of production and operation, safety and performance. As can be seen in the table, hybrid and fuel cell technologies are the cleanest and have the highest potential to reduce emissions. Yet, at this point, they are in the development phase and long-term reliability is yet unknown. This, coupled with the fact that they are exorbitantly expensive, makes them an unattractive choice. CNG technology is quite clean and over the years has proved efficient in reducing emissions when compared to diesel buses., Given their affordability and reliability, many cities around the world are moving to CNG buses. To further reduce emissions from CNG buses, hydrogen could be added to CNG to create hythane buses. This combines the strengths of both CNG

and hydrogen technologies. Hythane is a good transition technology; it has the potential to reduce emissions compared to CNG, while, at the same time, costs of implementing this option are comparable to CNG buses. Diesel technology already has reached its efficiency limits, and further reductions of NOx and PM emissions from diesel buses will require expensive tailpipe solutions. In the long run, if emissions standards get more stringent, then diesel buses will have difficulty in meeting their requirements.

Table 1. Comparison of Different Alternative Fuel Technologies

Criteria	Clean Diesel	CNG	Hythane	Hybrid	Hydrogen/Fuel Cell
Purchase Price (AUD)	@600,000	@700,000	@700,000	@1,300,000	@2,000,000
Fuel	Fuel is easily available	Can use existing fuel infrastructure.	Can use existing CNG infrastructure.	Can use existing fuel infrastructure.	Lack of fuel and fueling infrastructure.
Emissions	Higher emissions	Reduced emissions compared to diesel.	Reduced emissions compared to CNG.	Lower emissions.	No tailpipe emissions.
Technology	Mature technology	Old technology with new application.	Minor modifications to CNG technology.	New technology - unproven service record.	Technological barriers still to be overcome.
Safety	Most stable fuel	Natural gas stored in high pressure cylinders – high potential for leaks, explosion.	Natural gas and hydrogen stored at high pressure – potential for leaks and explosion.	Diesel is a stable fuel, but electric motor drive system presents potential for electrocution.	Hydrogen is stored in high pressure cylinders – high potential for leaks and explosion.
Performance	Proven service record	Limited range of operation.	Limited range of operation.	Flexibility due to dual power system.	Unproven technology and unknown durability.
Summary	Stable fuel, proven technology but higher emissions	Low emissions and proven technology. More expensive than diesel.	Very low emissions – combines strengths of natural gas and hydrogen.	Low emissions, but new technology and expensive.	Lowest on road emissions but unproven tech and very expensive.

Sources: CleanAirNet; DOE 2002; WSU 2004; Clark et al. 2007

The next section provides an overview of current emissions standards for public transport buses. Currently, emissions standards for buses are based on diesel technologies. Alternative fuel technologies are new, and emissions standards tailored

for their performance are yet to evolve. For example, at this point, alternative fuel buses such as CNG have to satisfy equivalent diesel bus emissions standards.

Emissions from diesel buses and emissions standards

Emissions from diesel engines are the byproducts of the combustion of the fuel. As per a British Petroleum (BP) fact sheet, for every 1kg of diesel burned, there is about 1.1kg of water (as vapor/steam) and 3.2kg of carbon dioxide produced. Unfortunately, as there is no 100 percent combustion, there is also a small amount of byproduct of incomplete combustion: carbon monoxide, hydrocarbons, and soot or smoke. In addition, the high temperatures that occur in the combustion chamber promote an unwanted reaction between nitrogen and oxygen from the air. This results in various oxides of nitrogen, commonly called NOx (BP 2002). Figure 2 shows the composition of different gases in diesel engine exhaust. Exhaust from the public transport buses typically contains:

- Particulate matter (PM) – soot
- Nitrogen oxides (NOx) – lung irritant and smog.
- Carbon monoxide (CO) – poisonous gas
- Hydrocarbons (HC) – smog
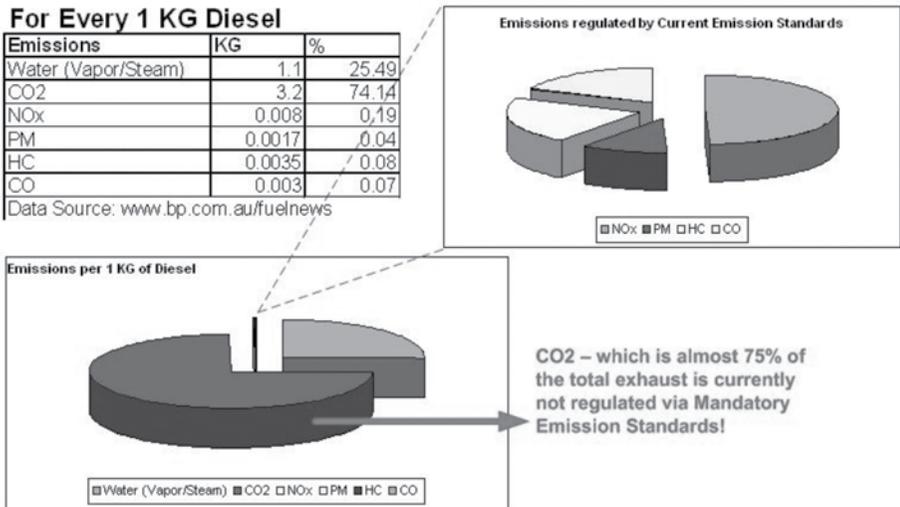- Carbon Dioxide (CO_2) – Greenhouse gas

Figure 2. Exhaust from diesel buses

Particulate matter is the general term for the mixture of solid particles and liquid droplets found in the air. Particulate matter includes dust, dirt, soot, smoke and liquid droplets. It can be emitted into the air from natural and manmade sources, such as windblown dust, motor vehicles, construction sites, factories and fires. NOx emissions produce a wide variety of health and welfare effects. NOx can irritate the lungs and lower resistance to respiratory infection (such as influenza). NOx emissions are an important precursor to acid rain that may affect both terrestrial and aquatic ecosystems. CO is the product of the incomplete combustion of carbon-containing compounds (Cohen 2005). CO contributes to green house gas effects and global warming. HC comprises unburned hydrocarbons in the fuel; it contributes to smog (blue haze over heavily populated cities). Although CO_2 emissions are more than 75 percent of the total emissions, and it is a green house gas (GHG) and has a huge global warming potential, it is still not mandatorily regulated by emissions standards. This will be elaborated further in the next section.

Emissions Standards

Emissions standards are minimum compliance requirements that set the upper limits for the amount of pollutants a vehicle can emit into the air. Emissions standards for *heavy duty diesel vehicles* generally limit the exhaust emissions of four pollutants (DieselNet; Walsh 2000): nitrogen oxides (NOx), particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO). Carbon dioxide (CO_2) emissions correlate to the fuel efficiency of the vehicle and are not limited by emissions standards. For example, the current European emissions standards do not set limits for CO_2 emissions—CO_2 is controlled through voluntary agreements with the automobile manufacturers. Australian public transport buses are subject to European Union (EU) emissions standards. They are a set of requirements outlining the limits for tailpipe exhaust emissions for new vehicles sold in Australia. The emissions standards are defined in a series of EU directives—emissions standards for new heavy-duty diesel engines are commonly referred to as Euro I through Euro V (DieselNet). Euro I standards were introduced in 1992, as shown in Figure 3, over the period 1992-2008; the permissible NOx emission limits have reduced by 75, PM limits have reduced by over 97 percent, HC limits have reduced by 58 percent, and CO limits have reduced by 67 percent. Currently, Australian public transport buses should satisfy Euro IV standards (DOTARS ; DOTARS 2004).
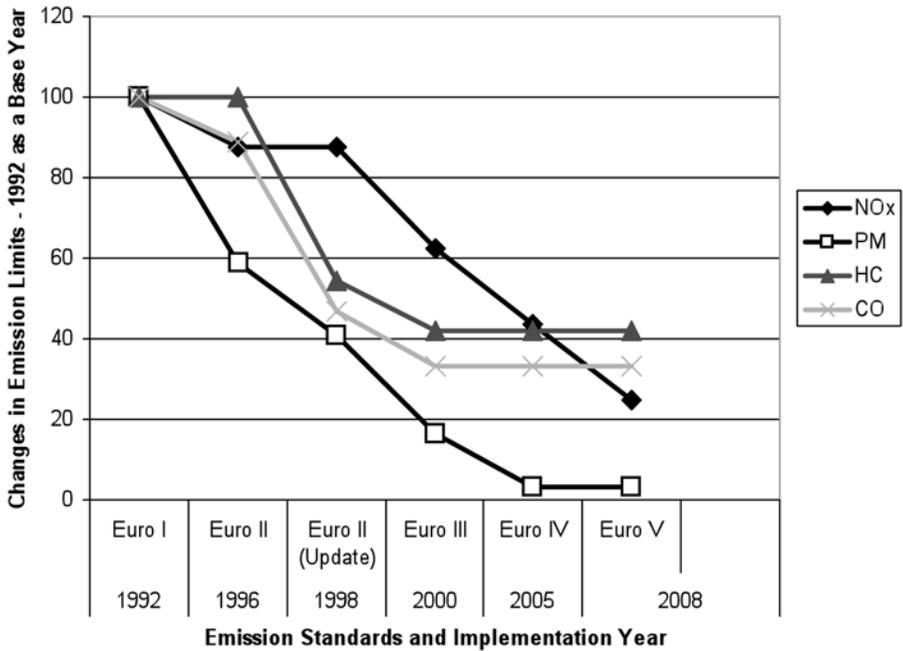
Figure 3. Changes in Emissions Limits, as a % of 1992 Limits

Results of the current stricter emissions standards could be witnessed within the next 15-20 years. As can be seen in Figure 4, over the next 10 years, NOx, PM, HC and CO are projected to decrease in Australia, but CO_2 concentration is forecasted to increase in the future (Walsh 2000; Schulte-Braucks 2006). Improvements in diesel technology and fuels have made this possible, and this transition has resulted in heavy-duty diesel engines that are more reliable, durable and less polluting than the diesel engines of the past (Scheinberg 1999). On the other hand, carbon dioxide emissions from road transport are forecasted to increase in the future due to increases in the number of vehicles. Carbon dioxide is not regulated through emissions standards; carbon dioxide emissions are a function of the vehicle's fuel efficiency, which is regulated with voluntary agreements with vehicle manufacturers.
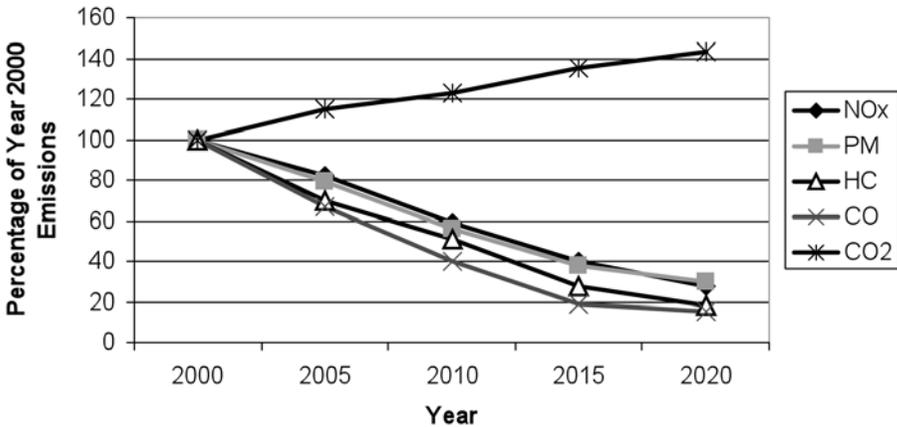
Figure 4. Projected Emissions for Key Pollutants for Australia

Discussion

CNG buses are inherently clean and are capable of reducing emissions, but, considering the 2026 clean air targets, Brisbane Trasnport should invest in hythane buses. Hythane buses will allow Brisbane Transport to considerably lower NOx and GHG emissions at only a marginally higher cost than CNG buses. Existing CNG buses can be easily converted to hythane buses with minor modifications. Natural gas regulators and carburetors are converted with only minor modifications, such as change of spring to accommodate the lighter gas (Nagalingam et al. 1983). Current hybrid and fuel cell bus technology is still immature and entails high investment costs for these buses. Although hybrid buses have higher fuel efficiency, the technology is undeveloped and has high maintenance and repair costs that do not warrant the investment in such expensive technology. Fuel cell and hydrogen buses are in their infancy and experimental phase—hence, huge investments in this technology should be avoided at this time unless subsidized by the Australian or Queensland government. The decision making process outlined in this research indicates that Brisbane Transport should invest in hythane buses for the future. Given the uncertainties about future policies and technology development, the hythane option entails incremental steps that build upon existing proven CNG technology. Also, hythane buses can use the existing CNG infrastructure with minor modifications. Brisbane Transport would be well positioned to convert its older CNG bus fleet into hythane with the introduction of stricter emissions stan-

dards, as hythane buses are better poised to deal with the uncertainties in future emissions standards.

Conclusion

Emissions standards can create incentives for the transition towards sustainability. Over the years, as emissions standards have become more stringent, bus manufacturers and fuel producers have developed numerous innovations (advanced engine electronic combustion control, fuel injection systems, and turbochargers to optimize performance) to increase thermal efficiency and reduce emissions in order to comply with the standards. Looking at the trends in emissions, it is observed that the aggregate amount of PM, NOx, CO and HC (mandatorily controlled by emissions standards) in the air due to transport has reduced over the years and is forecasted to further reduce, in spite of increases in number of vehicles. The framework developed in this paper gives insight into the interactions between the actors, rules and technology components of the transport sector and highlights the way policies affect technology development and actor decision making. Due to the uncertainties about future policy rules, the decision makers should take incremental steps (build on the existing competencies) to safeguard investments. Hence, we recommend an incremental change by investing in hythane technology buses for Brisbane Transport, as this will safeguard investments for the decision makers in the short term. If the government aims at accelerating the diffusion of alternative fuel technologies, it should create a stable policy framework. Such a policy framework would give an idea to the decision makers about the future progression of rules and regulations. As seen from the case study, voluntary agreements to reduce CO_2 have so far been unsuccessful; future emissions standards should aim at mandating CO_2 emissions.

Although decision making for the procurement of new buses is an important issue for transit authorities to achieve future environmental targets, little research has been done to date to assist the fleet manager in making these procurement decisions. This research aims to bridge this gap in the literature. The decision making process outlined in this research, based on forecasting, trend analysis and technology assessment, is adaptable to other types of infrastructure decisions to enable strategic procurement. We understand that there is a larger scope for improvement in terms of future research; this research was done for the Brisbane Transport and is by no means comprehensive, as it ignores many other sources of uncertainty and limitations faced by a decision maker during procurement. Future

research should be more comprehensive and could build on the analytical framework discussed in this paper to develop a decision making tool for the benefit of public transport authorities.

Acknowledgement

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