COVER SHEET

Investigation to Enhance Sustainable Improvements in High Speed Rail Transportation

Lara Brunello*, Jonathan Bunker* and Luis Ferreira*

Abstract Transport systems are essential for the life of modern societies and economies. A sustainable transport system can shape a sustainable development pattern and socio-economic attributes of urban centres and regions. The use of private cars and trucks is increasing in most countries, creating more congestion, accidents, pollution and energy consumption. Many governments desire to achieve growth in public transport to overcome these adverse trends. A massive shift toward an environmentally sound type of transport is crucial and railways are deemed to be one of the most sustainable modes. All over the world the railway industry is involved in a renewal to reform and up-date rail, prompted largely by environmental concerns. The trend is to develop speed-competitive systems to expand transportation capacity. The focus of the current research, which is at its commencing stages, is to investigate the opportunities to apply an alternative approach to railway operations to overcome the difficulty of high speed transport in servicing larger amounts of demand, while achieving minimum point to point travel time, in a viable and integrated environment for both passenger and freight services. The expected outcome of the research project is to present a framework that may be used to identify and evaluate the most cost-effective transport solution to service not only major cities, but also regional centres along an interregional rail corridor, thus providing greater benefits on local economies and to build a spine for future development.

Keywords high speed rail, sustainability, passenger and freight services

* School of Urban Development, Queensland University of Technology, 2 George St, Brisbane Q 4000, Australia

INTRODUCTION

The role of transportation in correlation with socio-economic development is well established and the relationship between economic growth and demand for transport has been widely investigated (European Commission 2001). It has also been assessed that activities need transport and transport offers chances for new activities (Vickerman 2005).

Transportation investment needs be supported with factors such as development programs and policies to result in economic development, and a sustainable transport system can provide support to develop a sustainable socio-economic pattern for urban and regional growth.

Sustainability

Sustainability is not merely described environmentally as capacity to renew resources, in economic terms it is maintaining the sum of capital stock of manufactured, human, and environmental assets at least constant to ensure that future generations have the same capability to develop as current generations (Pearce and Warford 1993). '*The Charter of European Cities and Towns towards Sustainability*', the renowned Aalborg Charter, states that the objective of sustainable development is "to achieve social justice, sustainable economies, and environmental sustainability" (European Commission 1994).

Environment

Environmentally speaking, the increasing use of passenger and freight road vehicles, along with aviation and maritime shipping, is the primary cause of growth in transport emissions. In Australia, and particularly in South East Queensland for its fast growing population, a development pattern of dispersed land use is more likely to provoke ever increasing use of private cars and trucks.

Environmental concerns are compelling many governments to rethink their programs and policies toward a more sustainable future. The Queensland Government has released the '*South East Queensland Regional Plan 2005-2026'* to confront the challenge of forecasting and regulating development for the next two decades (Minister Mackernroth 2005).

Wegener (2002) defines sustainable development as satisfying three basic conditions: its rates of use of renewable resources do not exceed their rates of regeneration; its rates of use of non-renewable resources do not exceed the rate at which sustainable renewable substitutes are developed; and its rates of pollution emissions do not exceed the assimilative capacity of the environment.

Railways have little part in transport emissions and are deemed to be one of the most sustainable modes of transport. Railway transport offers real advantages with respect to sustainable development if compared with the negative external effect of road transport; however in the past decades it has faced an ongoing decline due to some socio-cultural factors such as the increased mobility of individual transport modes. Renewed environmental awareness is prompting all over the world, and especially in Europe, a fundamental reorganization in the railway sector. Different models have been applied throughout the world to reform railways in their internal organization (Guihery 2002), but the common trend is to develop speed-competitive systems to expand transportation capacity.

Thanks to the use of more efficient locomotives, wider electrifications of lines and the ongoing research in new technologies, railways have great potential not only to overcome the environmental damage, but also to effectively compete with today's fastest means of interregional transfer such as air transportation.

Economic growth

There have been several attempts to overcome transport problems and different approaches and policies have been set. Among these, an important objective is that land use and transport policies should support economic growth. Transport improvements which improve access or enhance the environment can lead to increased economic activity and potentially to sustained economic growth.

It has been assessed that trade and industry have led both to increased income and traffic. Income growth allows car ownership to increase, which in turn favours urban sprawl, which itself requires increased car ownership. Eventually, car traffic growth has followed economic growth. Paradoxically although in some areas with high levels of congestion and environmental degradation, there is evidence that the problems caused by car traffic growth such as congestion, accidents, air pollution and noise, do contribute to economic decline (relocation of activities, increase of operating costs, flee of customers) and make it harder to achieve economic regeneration (Grieco 1994). Moreover breaking the link between economic growth and car traffic growth would enhance sustainability (Papon 2002).

Economically speaking, the issue to be addressed in this research is the economic-commercial feasibility of a new high speed rail transportation project, minimizing maintenance and operating costs. The ambitious objective of shifting volumes of freight traffic to high speed rail needs to aim to catch the attention of the private sector to invest in the funding of such projects.

Social equity

Governments need to identify policy instruments and adopt an overall strategy to meet higher objectives (protection of the environment, safety, social inclusion,

economic growth and equity). Key elements usually include reduction of the need to travel; reduction of road vehicle use; improvements in public transport.

Across society, increased car ownership encourages activities to relocate to satisfy the need of car owners and leads to a decline in public transport (May et al. 2004). Eventually it can only aggravate a situation where residents and pedestrians will be more exposed to air pollution and noise; bus users and those on essential journeys in city centres and at peak times will experience worse congestion; pedestrian and cyclists are more at risk from accidents. But in addition, people in lower income households, without cars, will often suffer from more limited accessibility to a choice of shopping and leisure facilities and job opportunities.

Socially speaking, the accessibility problem is the most important to note. The coverage, efficiency and quality of public transport may provide the alternative to car use and equally an enhanced form of transport for those who do not have cars available or with impaired mobility. However it needs to be coordinated with a set of improvements across a broad range of transport modes and accessibility opportunities.

The present research will concentrate on railways as the main mode to deliver an integrated and viable public transport. In fact they offer a great potential both through their consistent mass transit capability and as a highly sustainable means of transportation. Rail transport will be evaluated among other modes on environmental criteria (especially if considered their medium and long haul services) and High Speed Rail (HSR) systems will be analysed for their competitiveness.

This paper is structured as follows: the next section deals with the statement of the research objectives and describes the related problems. Afterward an overview of the methodology is presented and finally conclusions are drawn.

OBJECTIVES

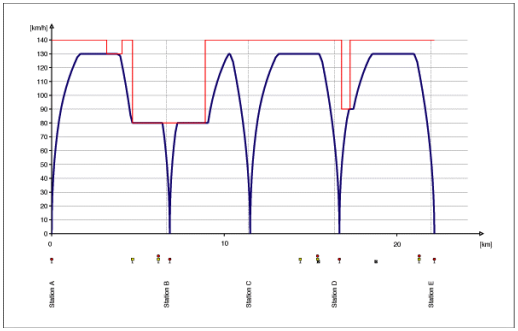
The broad aim of the research is to identify means to improve sustainable transport through fast, reliable and safe connections. Its specific focus is to investigate alternative approaches to current railway operations to address the following objectives:

- Increasing capacity and accessibility, servicing larger amounts of demand, while achieving minimum point to point travel time, and integrating both passenger and freight services to increase profits and economical feasibility;
- Develop an evaluation framework to assess the viability of the model and its application to different case studies.

Research Problems

The first stated objective attempts to solve a problem inherent in high speed transportation systems. In fact to reach speeds in the range of 250 km/h or higher and achieve reasonable efficiency, trains inevitably need to avoid excessive stopping along the line.

The following figure shows train speed in blue and speed limits in red: it is possible to deduct the loss of time due to accelerations and decelerations; if added to the waiting time at stations it can be easily understood that all this time is a value for high speed trains.



Speed/distance diagram (Swiss Federal Institute of Technology 1995)

The second objective, noted above, addresses the economic problem related to high speed railways, whose costs of construction and maintenance generally exceed governmental funding capacity. Passenger service alone is not sufficient as source of revenue and new investigations are needed to be carried out to find alternative funding approaches.

METHODOLOGY

Evaluation framework

In summary, the purpose of the research will be to assess the feasibility of an innovative HSR system for decision making. This study will attempt to develop a means to evaluate technological innovations to improve attractiveness of a rail

transportation system, capable of increased capacity and shorter journey times for the transfer of passengers and goods.

A milestone will be to assess the final value of the new HSR system capable of increased accessibility of both passenger and freight services. Guidelines for the use of the framework will be developed.

Land-use and Transport Impacts

Land-use and transport models are useful in assessing the impacts over time of a range of transport and land-use policies on both transport system performance and travel demand as well as the spatial, economic and environmental evolution of the urban region (Bonsall 2005).

Assessment procedures to help prioritize projects have normally focused on cost benefit analysis and evaluating alternative options, mainly to assess and mitigate environmental impacts. Recent research suggests that these procedures do not fully account for the impact of changes in transportation facilities (Noland and Lem 2002). Improvements in the travel environment create an addition to the demand influenced by income and population growth. This ‘induced’ travel is an important component of travel demand and depends upon substantial changes in service level. The effects of ‘induced’ travel can be categorized as either diverted trips on the short run (route switches and mode switches) or generated trips on the long run as spatial reallocation of activities (Litman 2001). To estimate whether travel demand is suitable an integrated nested model is needed, including a trip generation, destination choice, mode choice, and route choice model, where the accessibility term can measure the utilities of these components that are sensitive to the changes in service level. An additional land use model could predict longer term effects accounting for large-scale endogenous economic and demographic changes (Gerus 2006; Yao and Morikawa 2005).

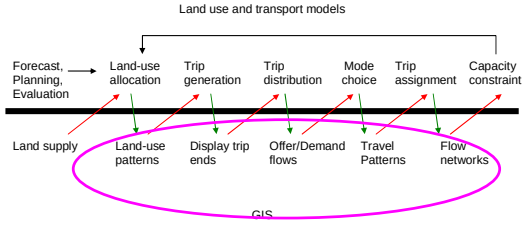
This relates to the research objective which is to establish the target level of passenger and freight demand for the feasibility configuration of the project. Since the aim of the research is to investigate ways of reducing travel time journeys for freight and passenger preserving a non-privileged public service along the line, the cost of the system will be supported if demand levels are appropriate. This could be assessed with the assumption of a significant change in the travel environment created by the project. So while transport-time savings are usually inversely proportional to lower transport costs (De Jong 2000), the research will attempt to derive both direct and indirect benefits. It will consider a modal shift toward rail and identify those possible improvements that are also most economically viable, environmentally and socially friendly.

The fundamental question that underlies the present research and drives the theoretical approach is: 'How would transport improvements shape a sustainable distribution of activities?' And certainly another question arises on how to evaluate such sustainability.

Indicators of sustainability and environmental performance can be useful for comparing modes, discerning trends and formulating appropriate policies. Use of the benchmark input-output models permits assessment of not only the direct performance of the transportation sectors, but also the supply chain impacts required for operation of the sectors. Consideration of indirect impacts is critical for assessment of the overall costs and impacts of particular products or services. There is considerable work to be done to improve the overall sustainability of the different transport modes. Alternative energy sources, better supply chain management and continuing attention to efficient transportation are important strategies. Likewise, reductions in global change and toxic pollutants would be desirable from the perspective of sustainable development (Hendrickson et al. 2006).

Strategic modeling can be backed up by software tools such as GIS (Geographic information system) that can facilitate the incorporation of 'place' into the analysis or by more specific tools such as AMI (Application of Metrics in Industry) to model and verify parallel systems in case studies. GIS is referred to be (Wegener 2004) the mainstream data organization of urban models, combining the advantages of spatial disaggregation (land use and transport network data in raster) and efficient network algorithms (land use transport models and air quality and noise propagation models in vector).

The following figure is an example of how GIS helps representing graphically data drawn from land use and transport models:



Interactions of GIS with land use and transport models (Dueker 2000)

When modeling rail accessibility, different simulation tools also might be useful in representing movements in the network such as Max Plus Algebra PETER (Goverde and Odijk 2002) and Open Track (Nash and Huerlimann 2004).

At the moment the review of different software packages will help understanding which would best suit the research plan to define and estimate an innovative HSR transport network. For example, Metro ARIA (Metropolitan Accessibility Index of Australia) (GISCA University of Adelaide 2000) might be useful to locate key services and understand population processes when looking at the Australian case study.

Whatever the tool used, the approach will endure the significance of the whole transport improvement project to shape a sustainable distribution of activities in the region or urban area of interest, as stated in the objectives.

Operational issues

Many proposed HSR lines have failed to attract sufficient investment to create new starts in part due to the conclusion that these systems would not likely cover their capital and operating costs and also provide reasonable profit for investors. Studies of their economic potential have commonly considered them as passenger carriers only, depending solely on ridership as a source of revenue. Yet it is likely that significant revenue potential exists for carrying higher value (express) freight as well – perhaps enough to substantially improve the economic viability of certain high-speed operations (Plotkin 1997).

Although bimodal operation of conventional rail lines has been studied and put into practice, little has been published on the possibility of introducing bimodal services on HSR type of track. In Europe its operation is starting to be discussed as a way to reap maximum benefit from the high investment costs. Yet governments do not have the necessary information on the feasibility of the system (Guirao et al. 2005).

While over the past decades the use of a rail line with shared operations has been investigated, there is little in the literature about the use of a single train to carry both passengers and goods, especially if run on a HSR line. A hint of a similar idea was only proposed for a vehicle called 'an intermodal coach' that could carry both passengers and two standard 10-foot containers (Boile and Gaspard 2002).

Financial viability

Ways to improve HSR systems will be presented, finding alternatives to make public transport more attractive and economically possible.

Attractiveness is going to be described through accessibility, reliability and convenience.

Financial feasibility is going to be looked at from the private sector's point of view for the introduction of services where more profit can be made.

It will be necessary to select an existing (or calibrated) model to assess the improved system, establishing the target level of passenger and freight demand for the feasibility of the project.

Europe and Australia case-studies

Predicting the impacts of integrated transport policies is a difficult task due to the multitude of concurrent changes of pertinent system variables (environmental impacts, networks and land use, workplaces and housing, employment and population, goods transport and travel).

The methodology to conduct the research to predict those impacts will not deal with people directly (stated preference) or indirectly (revealed preference), but with mathematical models, such as ILUTE (integrated land use, transportation, environment modeling system) (Miller and Salvini 2001) or TLUMIP (transport and land use model integration program) (Oregon Department of Transportation 2001) to simulate human decision-making and its consequences; since only this method is able to forecast still unknown situations and determine the effect of a single factor while keeping all other factors fixed.

To bring forward the research objectives, first the innovative HSR system will be described in its "desirable" aspects. Secondly an appropriate tool will be selected through review of the literature. Finally the evaluation of a specific scenario applied to different case studies will be proposed. Case studies might be chosen from the European context or from Australia. Reasons of this double choice are the following:

Europe: *HSR lines are spreading throughout Europe thanks to legislative packages released by the European Commission in the attempt to better connect the entire Union. Even if levels of transport demand support the HSR development, difficulties arise when looking at the infill of infrastructure.*

An interesting case study might be the HSR line of the 5th infrastructure corridor, which includes the 'Valle di Susa' region, where the population is struggling to prevent the construction through their territory. That piece of line is fundamental to connect Italy to France, but indigenous people do not get any benefit. The project in fact, as per every standard HSR line, does not provide many interconnections, keeping stops at minimum and being just a disturbance.

Australia: *South East Queensland is one of the fastest growing regions in Australia and immediate action needs to be taken to guide future development and to avoid unbearable overcrowding, congestion and safety and air quality problems.*

The development of an HSR system in this region will offer a faster public service for commuters, that if adequately spread will help interregional expansion with lesser moves to the city or its surroundings.

In both the above mentioned cases, the point made is that it is necessary to investigate an alternative approach to railway operations to improve accessibility.

Modeling accessibility plays an essential role in planning of an innovative transport system. It is useful to provide indicators to guide a sustainable future for the economic development of communities along the infrastructure corridor and it is fundamental to forecast the levels of demand capable of its feasibility.

The vision that lies behind this effort outlines and facilitates to develop a preferred land use pattern with a cluster structure, made of compact urban centres, diffused in the territory and focused around public transport hubs.

The research project will identify a spatial configuration to provide accessibility to a larger amount of demand with smaller, but numerous, stations around the cluster structure of metropolitan areas. Essential will be the consideration of the linkages of the local network with interregional services.

Technological investigation

It is important to promote new uses of rail transport in order to cut growth of greenhouse gases and reduce fuel consumption given that railways consume 1/20 of the energy used by private trucks (Watanabe 2003). The investigation on technologies for developing infrastructural advances for sustained top speeds or new rolling stock suitable for freight operations could reduce costs and improve overall performance. Building new HSR routes is not only environmentally sustainable and more favourable than expanding the highway network or increasing airport capacity; it also offers economic and social benefits (Monteith 2006).

Studies to compare current technologies have been carried out to allow the evaluation of decisions between SWSR (Steel Wheel on Steel Rail) and Maglev (Magnetic Levitation) systems (Miyamoto and Suda 2003). Results show that while a Maglev system requires high investment cost, they are fully grade-separated and minimize right-of-way needs, a SWSR system could operate on existing rail infrastructure or enable other rail operators to operate on its infrastructure. Selection of the appropriate technology will depend primarily on acceptable funding levels, transportation objectives and implementation schedule (Najafi and Nassar 1996).

New technology or a better application of existing technology can reduce the environmental damage caused by transport. One of these is the hydrogen-powered

fuel cell studied for road vehicles and recently also for trains (Duncan 2002). Other currently investigated improvements for rail operations include new traffic management systems, IT architecture for train command and control, train detection devices and automatic connection of trains.

The research will focus on some of these technologies to identify their gaps and opportunities and select an appropriate combination or options to apply to the model. In fact the innovative aspect of the model relies in the particular combination of these technologies and its final scope will be to provide an alterative configuration of railway operations useful for decision-making.

For this reason, aware that the adoption of new technology is surrounded by uncertainty, the model will need to be evaluated. To reduce uncertainty the research will be using the forecasting approach (modeling) and the scenario analysis with the application to case studies.

Before spending taxpayers' money frivolously on a new technology not yet in commercial service on the sole basis of preconceived notions, decision-makers need the support of a tool to jointly evaluate the results of this technology and to establish reasonable expectations for what that technology should accomplish. To provide such a structured decision process for example the Virginia Transportation Research Council developed a set of broad-based performance measures applicable to different rail systems, based upon a broad set of criteria, such as credibility, reliability, performance, safety and cost (Miller 2003).

The combination of new and existing technologies in the proposed model will constitute innovation and the research will attempt to offer an evaluation tool to measure the technical and economical feasibility of the new transportation system.

CONCLUSIONS

There is great potential in railways not only for their consistent mass transit capability, but also as a sustainable means of transportation. It is widely recognized that rail can provide reliable and high quality service, while other modes of transportation are becoming overwhelmed with congestion and safety and air quality concerns. In countries where a growing population is combined with a growing economy, passenger and freight demand is expected to increase. The challenge is to propose a most fulfilling transport service to respond efficiently and promptly to people travel and freight movements. The aim of the research is to assess the possibilities of technological improvements to enhance HSR performance and provide the appropriate land-use and transport framework, for decision making in planning, when dealing with innovative transport systems.

This paper has described the sustainability problems we are facing today in transportation, and has discussed the major strategies to develop an alternative approach.

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