Regional development via high-speed rail

A study of the Stockholm-Mälaren region and possibilities for Melbourne-regional Victoria

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Abstract

The purpose of this thesis is to examine, based on a study of the regional high-speed corridors in the Stockholm-Mälaren Region, the possibilities for regional high-speed rail in Melbourne-regional Victoria (Australia) to improve accessibility, and achieve regional development and balanced growth between the capital and its surrounding regions. It deals with the concept of 'regional' high-speed rail, a variant of classic high-speed rail that serves centres along regional corridors stemming from a large city and whose travel purpose includes a high share of daily commuting and occasional business and leisure travel with journey times of up to two hours.

The literature review reveals an emerging market for regional high-speed rail, which also has the potential to stimulate regional development and give rise to a complementary polycentric structure, subject to appropriate supporting conditions. The link between high-speed rail and regional development is based on the assumption that increased accessibility expands labour markets and offers people and firms wider location choices by permitting longer commuting.

The Stockholm-Mälaren region analysis includes a review of the past-studied Svealand line, a comparative study of city groups and case studies. Key outcomes are summarised as follows:

- Regional centres have in general strongly benefited from a high-speed rail connection, a finding supported by steadily increasing commuting, and population and job growth.
- Cities within one hour of Stockholm experienced the greatest increase in commuting that was matched by consistently positive population and emerging job growth; these centres have benefited the most from high-speed, which reinforced ongoing activities.
- Small-medium cities greater than one hour from Stockholm suffering population and job decline experienced recovery to neutral or positive growth with the introduction of high-speed; these centres depend on supportive strategies to fully capture its benefits, particularly those that foster inter-city exchange and the formation of city networks.
- Supportive strategies for high-speed rail include: public transport coordination, station redevelopment, establishment of public offices and measures for inter-city exchange.

Regional high-speed rail is proposed in Melbourne-regional Victoria based on the application of speed enhancements (to 160, 200 and 250 km/h) on existing rail corridors, which reduce travel times between Melbourne and regional centres, facilitating increased commuting and stimulating regional development. The key outcomes are summarised as follows:

- The improvement of inner lines to 200-250 km/h and outer lines to 160 km/h achieves an efficient balance between improved accessibility and economy in the short-medium term; future enhancements include peripheral links and higher speeds on outer lines.
- Upgrading lines to true ‘high-speed’ status requires electrification, modern signalling and track improvements, which deliver improved run times for the higher investment.
- Estimated demand growth factors range from 1.4 to 2.0 depending on speed and route.
- Positive regional development effects are expected if appropriate supportive strategies are applied, especially ones that support economic specialisation and city networking.

Sammanfattning

Syftet med detta examensarbete är att analysera möjligheterna, baserat på en studie av snabbtågssystemet i Stockholm-Mälarregionen, för regionala höghastighetståg i region Melbourne i Australien. Att förbättra tillgängligheten och uppnå regional utveckling och balanserad tillväxt mellan huvudorten och den omgivande regionen. Det handlar om höghastighetståg, som försörjer orter längs regionala korridorer utgående från en större stad där resorna innehåller en hög andel dagpendling samt affärs- och fritidsresor med upp till två timmars restid.

Litteraturstudien visar på en framväxande marknad för regionala höghastighetståg som har möjlighet att stödja den regionala utvecklingen och ge upphov till en kompletterande nätverksstruktur mellan omgivande mindre orter. Kopplingen mellan höghastighetstrafik och regional utveckling bygger på antagandet att ökad tillgänglighet expanderar arbetsmarknaden och erbjuder människor och företag större lokalisering genom att tillåta längre pendling.

Analysen av Stockholm-Mälarregionen omfattar en studie av Svealandsbanan och en jämförande studie av den regionala utvecklingen. De viktigaste resultaten är enligt följande:

- Regionala centra har i allmänhet starkt gynnats av snabba tågförbindelser, ett konstaterande som stöds av stadig ökande pendling samt ökad befolkning och sysselsättning.
- Städer inom en timmes restid från Stockholm upplevde den största ökningen av pendling som matchas av befolkningsökning och nya arbetstillfällen. Dessa städer har gynnats mest av den kortare restiden, vilket förstärkte den pågående förändringen.
- Små- och medelstora städer, längre än en timme från Stockholm med minskande befolkning och arbetstillfällen vänder till neutral eller ökande tillväxt med införandet av höghastighetståg. Stödjande strategier behövs för att dessa orter ska kunna maximera sin utveckling, särskilt de som aktivt stödjer regionalt samverkan och skapandet av nätverk mellan städerna.
- Stödjande strategier för höghastighetståg är: samordning av allmänna transporter, upprustning av resecentra, etablering av arbetsplatser, effektiv regional samverkan.

Regionala höghastighetståg föreslås i Melbourne-region med höjd hastighet (till 160, 200 och 250 km/t) i befintliga järnvägskorridorer vilket minskar restiderna mellan Melbourne och kringliggande regionala centra. Detta underlättar en ökad pendling och stimulerar till en regional utveckling. De viktigaste resultaten sammanfattas enligt följande:

- En förbättring av inre linjer till 200-250 km/t och yttre linjer till 160 km/t ger balans mellan ökad tillgänglighet och ekonomi på kort och medellång sikt, framtida förbättringar kan vara satsningar på sekundära linjer och högre hastigheter på yttre linjer.
- Uppgradering av linjer till "höghastighetstrafik" kräver elektrifiering, nya signalsystem och bättre spår. Detta ger ytterligare förkortade restider för investeringarna.
- Beräknad tillväxtfaktor för efterfrågan varierar mellan 1,4 och 2,0 pga hastighet och linje.
- Positiva regionala utvecklingseffekter kan förväntas om stödjande strategier tillämpas, särskilt de som stöder den ekonomiska specialisering och regional samverkan.

PREFACE

My motivation for this thesis stems from a growing interest in railway systems that developed prior to and during the 3½ years I worked at the Association of European Railway Industries in Brussels, Belgium and subsequently in my Master studies at KTH in Stockholm, Sweden, as well as interest in sustainable regional planning. The two aspects seemed compatible and I have been impressed with the many ongoing developments in Europe and around the world in high-speed rail. Taking high-speed rail as a base, I wanted to explore how it could be applied on a regional scale and how it might provide improved connections between smaller regional centres and a large city and act as a facilitator for development of those regions. It seemed to me to be of relevance at a time when larger cities are under pressure from population growth and novel transport and planning solutions could be considered that lead to a more regionally dispersed structure as a sustainable alternative to the expanding megacity. I was fortunate to have the opportunity to study in a region where regional development is being pursued via high-speed rail, and hence the Stockholm-Mälaren region was an inspiration for this thesis. It is not possible to cover all aspects of this broad subject in a Master thesis but it is hoped this work can lead to further research and discussion on regional development via high-speed rail.

Aside from my own motivation for this thesis, there are several people to whom I owe sincere thanks for their support, encouragement and advice throughout this thesis work. First of all to my supervisors, Oskar Fröidh and Joel Franklin, without whose support from the inception of this thesis it would not have been possible to complete; I wish to express my gratitude to you for assisting me in shaping the topic and scope of the thesis and offering support throughout its writing. Oskar Fröidh's previous work on regional high speed trains was an inspiration to this thesis work. I would also like to thank Professor Bo-Lennart Nelldal and Anders Lindahl for their valuable input and guidance, Gustaf Lindström for his input as opponent, as well as other members of the KTH Railway Group and the Transport and Location Analysis division whose work and input contributed to this thesis. Finally, I would like to thank my parents and friends who provided moral support and encouragement through the often demanding periods in the months of research and writing of this thesis.

Michael Bayley

18 June 2012

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1 INTRODUCTION

1.1 Background

High-speed rail is acknowledged as a fast environmentally-friendly means of transport that is most competitive over medium-long distances. Regional high-speed rail, a variant on classic endpoint high-speed rail serving centres along regional corridors emanating from a large city, has been demonstrated to have the potential to exploit this medium-distance market niche. A case in point is the Svealand line ('Svealandsbanan' in Swedish) in the Stockholm-Mälaren Region, which achieved a seven-fold increase in travel demand following the introduction of high-speed rail and retains 30% of the regional transport market. While the short-term effects on travel patterns are evident, the longer-term effects on regional development are slower to emerge and harder to discern. Commuting patterns, as well as changes in population and jobs, may provide indications on regional effects with support from relevant literature.

Regional development is often cited as a positive consequence of high-speed rail, whereby regional centres are effectively brought closer to one another and the dominant city through improved accessibility: reduced travel time and higher trip frequency. Improved accessibility enables people to commute longer distances in the same time as previous and offers firms new location opportunities; in the longer term, a more regionally-dispersed settlement pattern may emerge: the growth of regional centres with development concentrated around railway nodes and a simultaneous easing of population growth (and reduced urban sprawl) in the dominant city. Not only is this pattern of growth a potential solution to the development challenges of a region, it might also generate positive socioeconomic and environmental effects.

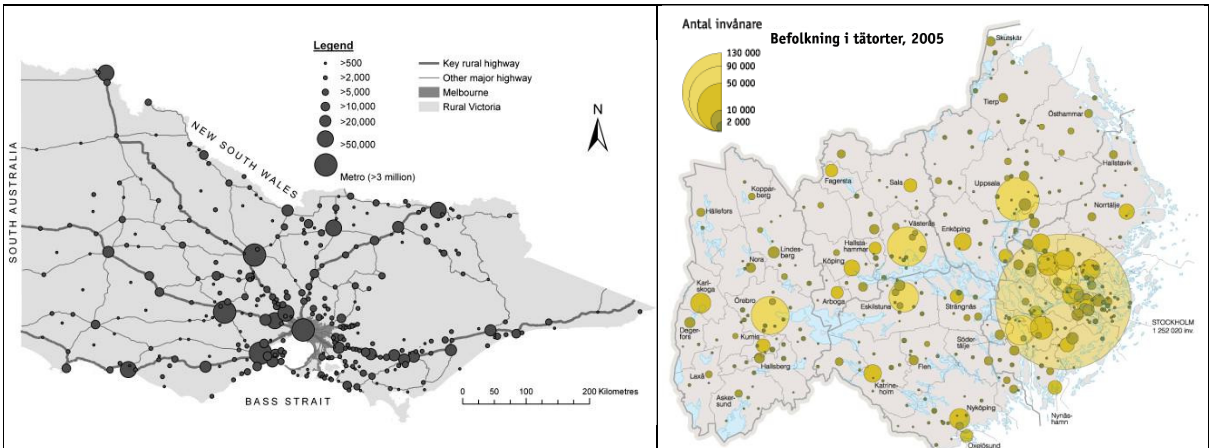
This thesis studies the effects of regional high-speed rail on the travel market and behaviour, and seeks out the emergence of longer-term regional effects. Beginning with the experience of the Stockholm-Mälaren Region, high-speed rail is applied to Melbourne-regional Victoria where its short-term effects on passenger travel demand are estimated and the medium-long term effects on regional development are theorised.

1.2 Problem definition

The city of Melbourne, in Australia, is the largest and overwhelmingly dominant in its region. With a population in excess of 4 million and growing, it outstrips its largest regional satellites by between 20 and 40 to 1, which are situated between 75 and 150+ kilometres from the capital. Transport links consist of relatively direct and high-capacity roads and rail and coach services of varying frequencies; 'fast' rail services achieve a modest maximum speed of 160 km/h. Road is overwhelmingly the dominant mode for passengers and freight. Melbourne is under severe pressure to accept future population growth and regional development has been proposed as a means of absorbing some of this growth. While distance and existing transport links hamper efforts to achieve growth in regional Victoria, improved accessibility brought about by high-speed rail might raise the potential for regional development.

The Stockholm-Mälaren Region (commonly referred to as the Mälaren Valley; Mälardalen in Swedish) comprises the Swedish capital of Stockholm and the region west of it surrounding Lake Mälaren. The area takes in a population of around 3 million, of which 2 million is in the greater Stockholm region; the largest regional centres have populations of between 60,000 and 140,000 and are situated between 65 and 150+ kilometres from the capital. All significant regional centres are linked to Stockholm via regular regional high-speed rail services capable of 200 km/h operation, thus enabling good accessibility and fast commuting between centres.

Comparing Melbourne-regional Victoria and Stockholm-Mälaren, the two regions share some important characteristics: their regional centres range in similar population size and distance from the capital, rendering them comparable in scale; the difference is Melbourne is a larger and more regionally dominant city than Stockholm, while the regional centres of Stockholm-Mälaren are more numerous and on average larger than those of Melbourne-regional Victoria. Transportation links vary more markedly: aside from good-quality highways common to both regions, Stockholm-Mälaren Region offers regular high-speed rail services while Melbourne-regional Victoria offers rail and coach services of varying speed and frequency. Differences in public transport supply between regional centres affect travel patterns and the propensity for regional development. In this thesis, Stockholm-Mälaren serves as an example of what might be achieved in the Melbourne-Victoria region with the introduction of regular high-speed rail.



Larger scale version of maps: p. 114 (Appendix 1)

Figure 1.1: Regional population size and distance (Melbourne-Victoria & Stockholm-Mälaren)
Sources: McGrail, R. & Humphries J. (2009); Sveriges Nationalatlas (www.sna.se/webbatlasgis/)

1.3 Objectives and scope

The goal of the project is to examine, based on a study of the regional high-speed corridors in the Stockholm-Mälaren Region, how high-speed rail could be applied to regional corridors in the Melbourne-country Victoria region of Australia and what the short-term transport-related and medium-long term regional effects might be.

The project will overview the high-speed rail network in the Stockholm-Mälaren region of Sweden, summarising the physical characteristics and services offered on each line. It will then consider the short-term effects of the introduction of high-speed services on the travel market, with a focus on the previously studied Svealand line, in terms of ridership, commuting and market share; as an extension, the emergence of longer-term regional effects (spatial and settlement changes) will be briefly examined based on indicators (population and job changes, extent of commuting) supported by literature. The outcomes of the Stockholm-Mälaren study will then be applied to Melbourne-regional Victoria as a proposal for a regional high-speed rail network based on the existing corridors. The short-term effects on passenger demand will be estimated and the longer-term regional development effects hypothesised based on the Swedish experience and effects suggested by the literature.

1.4 Organisation of thesis

The thesis is organised sequentially on the basis of the study scope as follows:
Chapter 2 addresses the theoretical basis for regional high-speed rail and its effect on regional development and reviews current knowledge and empirical findings on their relationship; the purpose is to establish some preconditions on the development of a new regional rail system.
Chapter 3 describes the overall approach of the thesis and specific quantitative methods used.
Chapter 4 reviews regional high-speed rail services in the Stockholm-Mälaren Region, noting short-term effects on the travel market and eliciting emerging longer-term regional effects.
Chapter 5 reviews the regional railway network of Melbourne-regional Victoria and proposes enhancements to raise the system to true high-speed, the resulting short-term transport effects of which are estimated and the longer-term regional development implications theorised.
Chapter 6 summarises the outcomes of the preceding chapters and draws general conclusions on the possibilities for regional high-speed rail and its implications for regional development in Melbourne-regional Victoria; a recommendation on the way forward is also suggested.

1.5 Delimitations of study

In a topic as potentially broad as regional development via high-speed rail, it is necessary to specify the components not addressed in this study.

By the very nature of the topic, the thesis is limited to regional high-speed passenger services that constitute the short-medium distance travel market with distances of 50-200 km (up to 2 hours) from the capital city. It does not consider freight, long distance high-speed or suburban commuter services; interfaces with the latter are mentioned where appropriate. Implications for regional development are based on trends observed in the Stockholm-Mälaren region (for high-speed rail connected cities), city case studies and evidence from the literature. Analytical studies consider only trips between regional cities and the capital, since this is the dominant market of interest. Regional effects are not considered in any detail from a socio-economic or environmental perspective and there is no socio-economic evaluation or polycentric study.

2 THEORETICAL BASIS AND LITERATURE REVIEW

2.1 The market for regional high-speed rail

2.1.1 Defining regional high-speed rail

Regional high-speed is a variant on classic endpoint high-speed rail that serves centres along regional corridors stemming from a large city. The travel purpose includes a relatively large share of daily commuting as well as occasional business and leisure travel. Trip length varies from up to 1 hour (for daily commuting) to between 1.5 and 2 hours (for occasional business and leisure travel). The main travel purpose for regional high-speed 'daily commuting' is to a large extent lacking in interregional (long-distance) high-speed, due to trip times commonly exceeding the generally accepted threshold for daily commuting of one hour. Generation of daily commuting travel is a function of travel time (≈<1 hour) and time-budget constraints, as depicted in Figure 2.1. Travel times are approximate but overall it can be assumed that times made within around one hour generate the most travel. The dashed line represents the effects of regional high-speed over the general case: increased travel for longer regional (and inter-regional) journeys, based on lower generalised travel costs due to high comfort, good service and an acceptance of longer travel times for greater distances by high-speed (Fröidh, 2003).

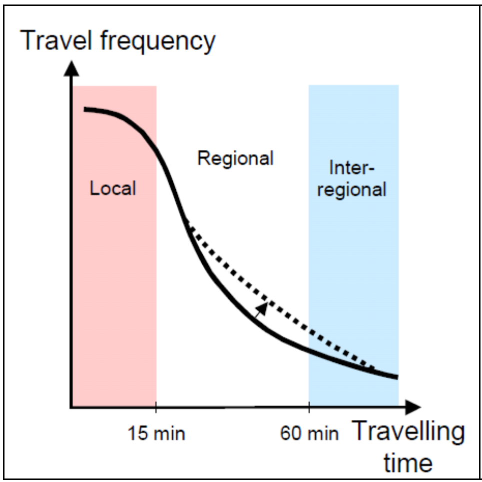


Figure 2.1: Daily commuting as a function of travel time; the effects of regional high-speed rail
Source: Fröidh (2003)

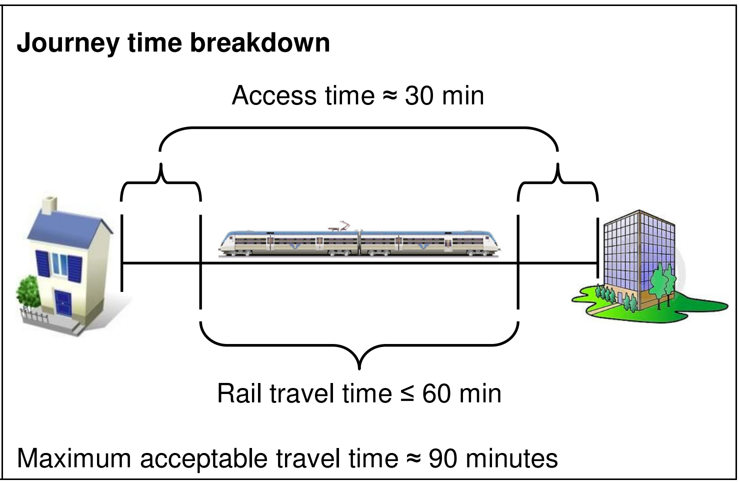


Figure 2.2: Breakdown journey time to/from work
Source: Basis of travel times from Nelldal (2011)

The total journey time breakdown is depicted in Figure 2.2. Access time between home-train and train-work is assumed to be around 30 minutes; commuting time by regional high-speed rail is up to 60 minutes; the total maximum door to door travel time is 90 minutes. The access time depends on the proximity of the home and workplace to the train station and the ease of access between them (public transport connections, parking, etc). An access time in excess of 30 minutes must be offset by a shorter rail travel time. As these times are practical maxima, a shorter overall commuting time (≈60 minutes) will attract a greater number of travellers.

2.1.2 The emerging market for regional high-speed rail

High-speed rail is most competitive against other modes in the medium-long distance market, corresponding to between 100 and 600 kilometres, beneath which car is faster door to door and above which plane starts to become quicker. High-speed rail is defined by the European Union as equal to or greater than 250 km/h for specially built high-speed lines and between 200-220 km/h for specially upgraded high-speed lines (UIC, 2010). Figure 2.3 (right) depicts the expected market share for high-speed trains >200 km/h as a function of distance, showing rail exerting competitive pressure for distances over 100 kilometres. The greatest potential for high-speed rail is between 300 and 600 kilometres (2-3 hours), although small-medium cities near large cities indicate the highest growth potential for journey times less than 1.5 hours for new users and commuters (Álvarez and Fröidh, 2009).

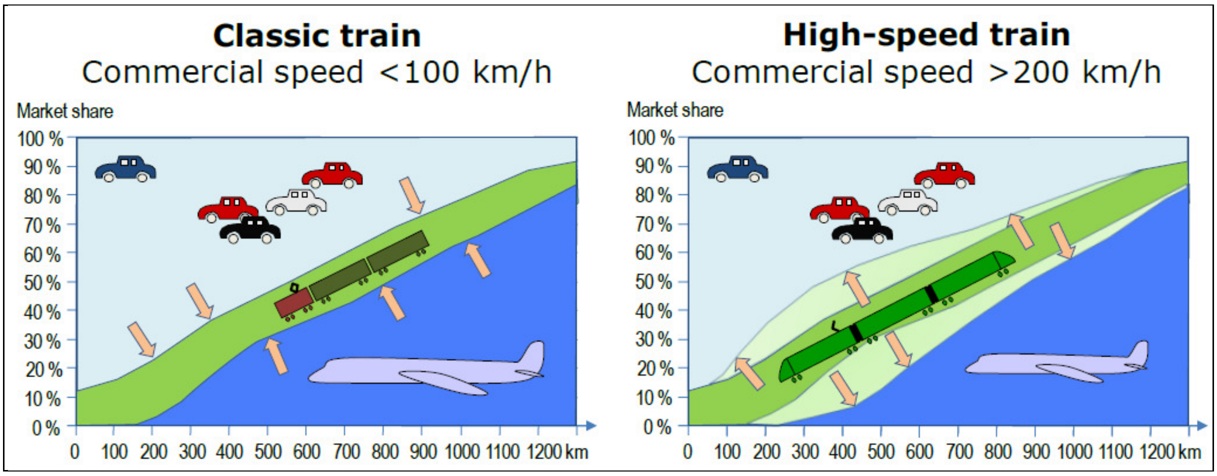


Figure 2.3: Competitive pressure between modes as a function of train's average speed
Source: Gröna Tåget (Fröidh, 2012)

Figure 2.4 depicts travel time against distance for different classes of rail compared to other modes, and reveals high speed-trains on high-speed line (HSL - defined as ≥250 km/h) as the fastest mode from around 90 kilometres onwards.

When considering regional and inter-regional journeys up to 300 km, as is the case for travel between regional centres in Stockholm-Mälaren and Melbourne-regional Victoria, the path-time profiles become more favourable to regional high-speed rail, as depicted in Figure 2.5. Access time is assumed to be 30 minutes. With a maximum speed of 200 km/h and average speed of 120 km/h (using high-speed "Inter-Regio" regional trains), the train is faster than the car for distances over 30 kilometres and achieves 130 km in 1.5 hours, which is considered an acceptable interregional commuting time. Raising the operating speed to 300 km/h increases the distance for daily journeys to 200 km (Nelldal, 2011). Regional trains with a maximum speed of 130 km/h (average speed 75 km/h) cannot outrun car over these distances and it is assumed that a maximum speed of 160 km/hr (average speed 90 km/h) is comparable to car.

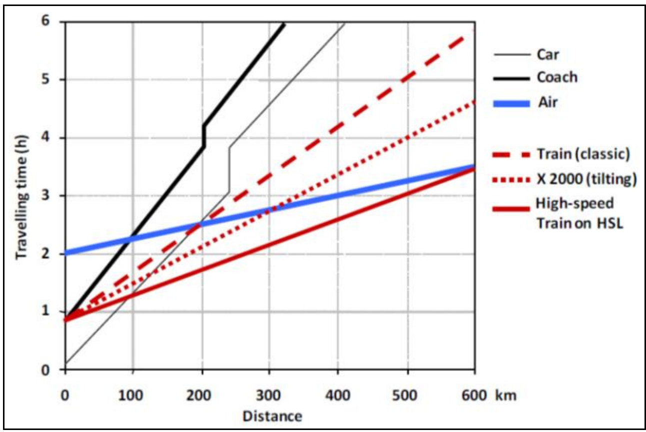


Figure 2.4: Path-time diagram with door-to-door travel for different modes of transport
Source: 'Gröna Tåget' (Fröidh, 2012)

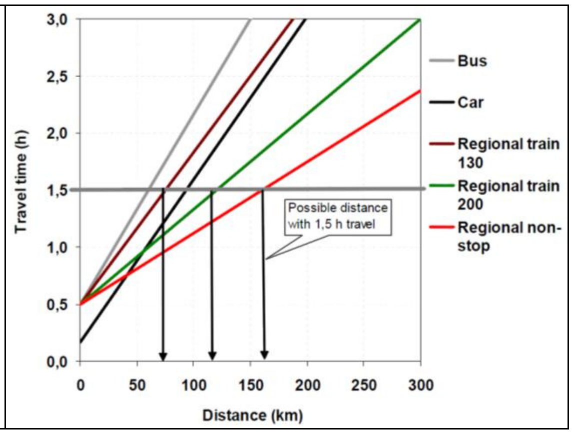


Figure 2.5: Path-time diagram with door-to-door travel for interregional and regional
Source: Nelldal (2011)

Interregional commuting trips of between 130 and 200 km for maximum operating speeds of 200 and 300 km/h respectively can be achieved in around 1.5 hours. For occasional trips (1-2 times a week) longer travel times might be acceptable and thus longer distances achievable.

Travel time is the primary factor in the generation of new travel and key determinant in travel mode choice for the medium-long distance regional-interregional market in which regional high-speed rail is included. Other factors are however also important. An analysis of the long-distance passenger traffic market in the *Green Train* project finds that high-speed trains have strong market potential, provided that: (Fröidh, 2012)

- Journey times are short and attractive, in particular in the business travel market
- Fares are low, in particular in the private travel market
- Frequency of service is high, in particular on short and medium-length routes
- Good comfort and service can be offered

Frequency of service is of elevated importance for shorter distances since waiting time makes up a greater proportion of total journey time sacrifice; this is compounded when connecting trips and changes are involved (Fröidh, 2012).

In several European countries, regional high-speed rail services operate on the purpose built high-speed network and services may either be offered by the classic long-distance service or special medium-distance regional services. The structure of the high-speed network (radial emanating from metropolis versus grid or networked) has implications for its suitability for regional high-speed travel, as does location of stations (centrally-located versus peripheral). Ureña and Coronado (2009), in reference to the development of the French and Spanish high-speed rail networks, identify the emergence of complex network structures that enable high-speed rail to be utilised for purposes other than long distance travel between large cities, including daily commuting trips of up to 200 km, metropolitan travel over 100 km and new high-speed regional services.

Martinez et al (2010) assesses the role of medium distance high-speed rail services in Spain. Described as ‘regional HSR services’ and operating as *AVANT* and *AVE-LANZADERA*, they emerged from an increasing demand for intermediate distance (-200 km) travel following the introduction of high-speed rail and a preference over low quality and diversified traditional regional rail services. Services can be divided into ‘HSR only’ and ‘mixed traditional-HSR’ according to the infrastructure, as depicted in Figure 2.6, with the former operating at slightly lower speeds than long-distance high-speed. The study found that for distances between 150 and 270 km, the number of passengers was large with no intermediate stops but lower if there are intermediate stops; for distances below 100 km, passenger numbers are only large if one of the cities is a metropolis or two smaller cities have central (rather than peripheral) stations; almost all regional high-speed rail services use exclusively HSR infrastructure and those that use a combination of HSR and traditional infrastructure are much slower, have more stops and attract very few passengers. Finally, it suggests that regional high-speed rail services are necessary for commuting to be viable from a few cities up to 200 km from the metropolis. (Martinez et al, 2010)

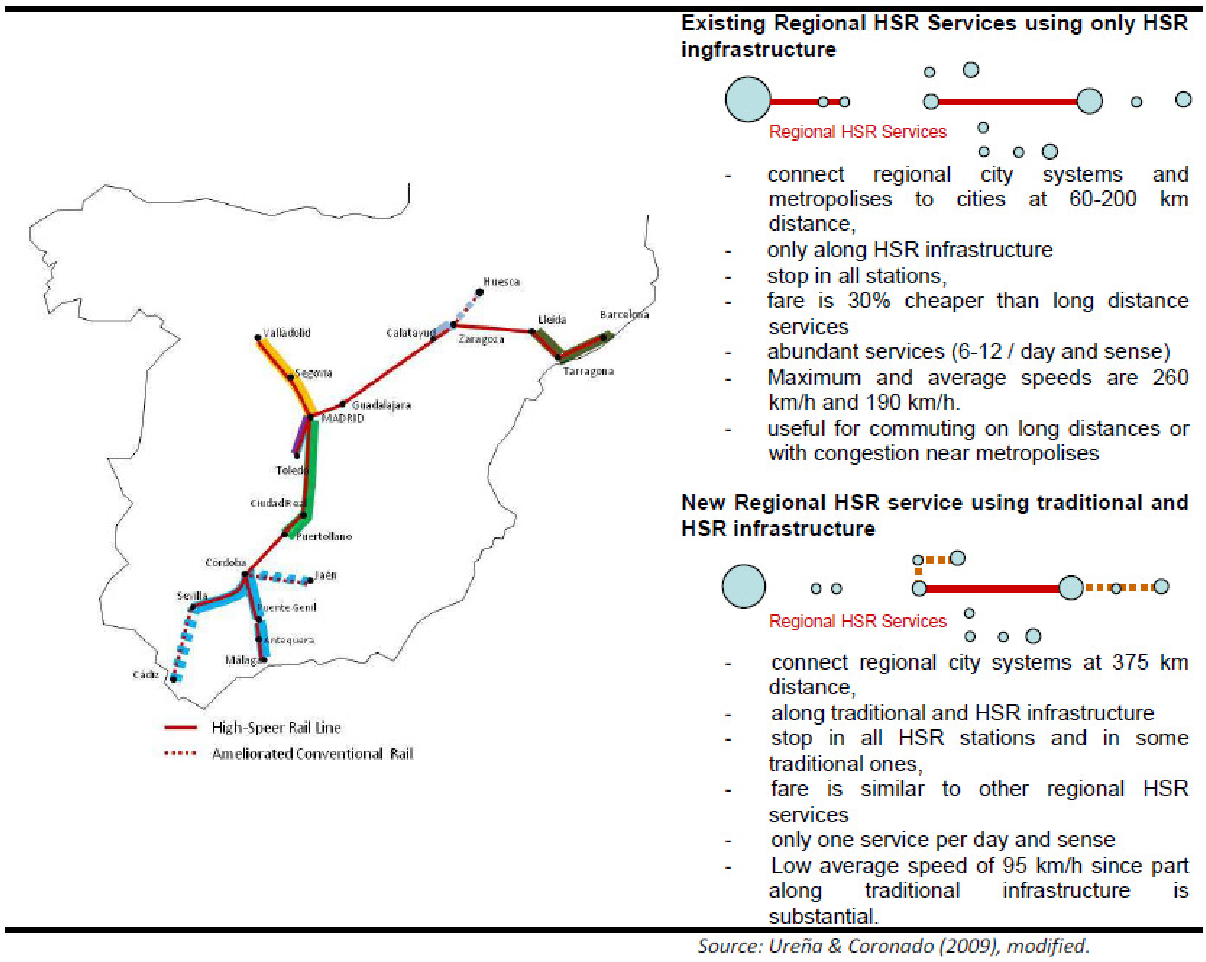


Figure 2.6: New Regional HSR service in Spain using traditional and HSR infrastructure
Source: Martinez et al (2010)

Torchin et al (2009) examine high-speed rail at national, regional and local levels, considering approaches taken in France, Belgium, the Netherlands and England to serve the short-medium distance trip market. It considers the then sole example of regional high-speed rail in France: the TERGV operating since 2000 in the Nord-Pas de Calais region, which uses TGV trains on the high-speed network for part or all of a line with the aim of bringing all the conurbations in the region to within one hour of the metropolis of Lille. By comparison to conventional TER, average journey times have been halved and traffic has increased between 13.1 and 27.5% on lines with good TERGV services between 2004 and 2005, compared to a regional increase of just 3.2%. (Torchin et al, 2009)

Figure 2.7 compares regional high-speed services in Spain and Nord-Pas de Calais (France) based on different performance criteria. The notable features are that the cities lie between 50 and 150 km from their parent city, travel time is roughly halved in all cases with high-speed rail and there is a marked drop in ticket price from national to regional high-speed trains.

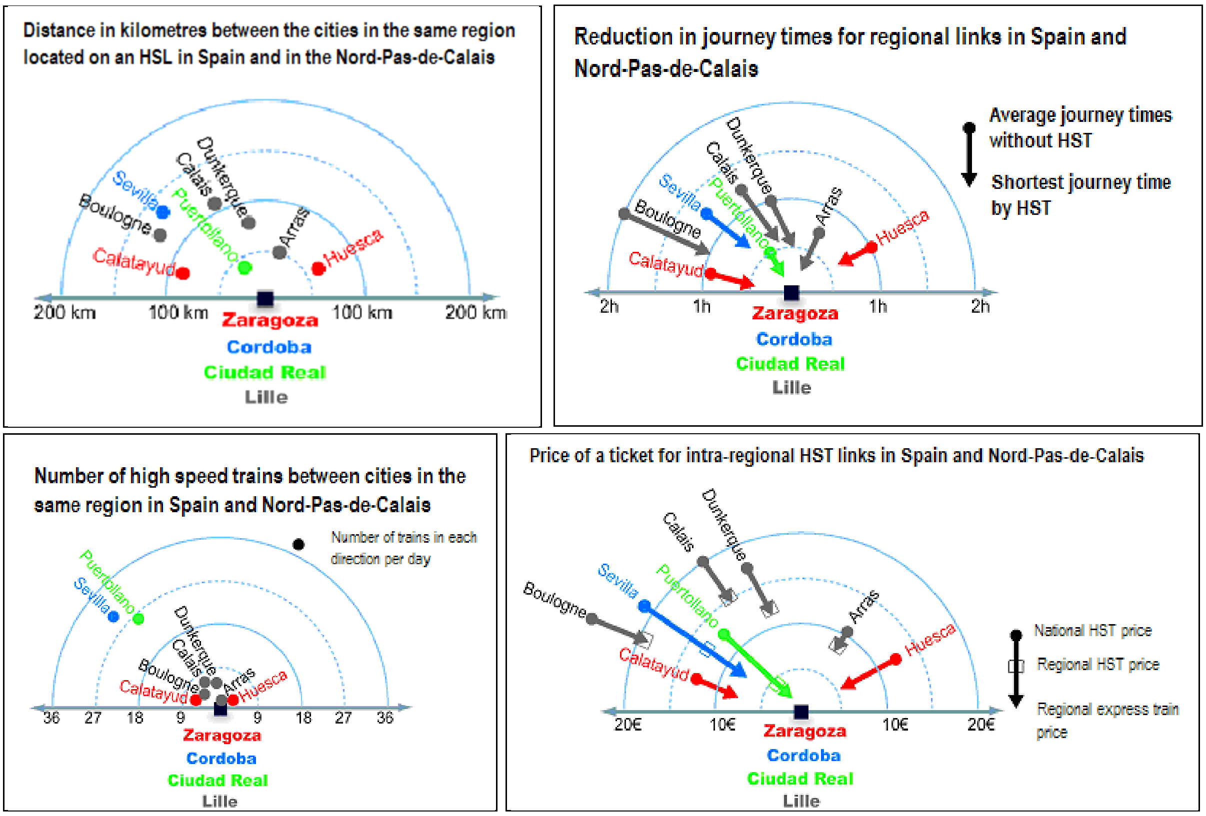


Figure 2.7: Comparison of regional high-speed services in Spain and Nord-Pas de Calais
Source: Torchin et al (2009)

Steer Davies Gleave (2004) undertook case studies in high-speed rail development, transport markets and appraisal processes in Britain and six other countries. The market for high-speed rail was found to be the largest where a large market exists for travel over distances of around 200-800 km and especially in the range 300-600 km; it offers little benefit for journeys shorter than 150-200 km. High-speed rail offers very high capacity but for there to be sufficient travel demand to effectively utilise capacity requires large cities a suitable distance apart or several population centres accessed from the same high-speed route.

2.2 Impact of regional high-speed rail on travel behaviour

The introduction of high-speed trains offers various transport supply improvements, the most important being travel time reductions; other improvements that may accompany travel time reductions are increased frequency, improved comfort and onboard services, and lower fares. Positive changes to transport supply invariably lead to an increase in travel, termed 'induced travel demand', that is made up of newly generated trips and trips from other modes: car and bus (and truck in the case of freight) for medium-distance travel. Most new passengers opt for high-speed rail on account of the travel time reductions, which increases 'accessibility', the capacity to reach different locations, activities, goods and services and thus provide increased opportunities for work, business exchange, trade and leisure (Rodrigue, 2009; Litman, 2011).

Increased accessibility enabled by high-speed rail expands labour markets, which is reflected in increased levels of commuting. In the longer term, increased accessibility can affect the location decisions of individuals and firms: individuals may opt to move to areas that offer quality of life benefits in exchange for commuting longer distances to work; firms may find new areas attractive to relocate to (due to lower land costs and/or location advantages) whilst retaining access to enlarged labour markets and benefiting from agglomeration effects. These effects generate new activities, which stimulate new travel needs and new traffic patterns.

2.2.1 Predicting the short-term effects of supply improvements

When planning new investments, forecasting models are required to estimate the short-term effects; travel forecasts may be estimated by new travel forecasts or demand elasticities. New travel forecasts include established models such as the 'four-step' model, where calculations are divided up into four steps (trip generation, trip distribution, mode choice, route choice), and the logit model which is used to describe the impact on demand based on behavioural and utility theory via Revealed Preference (RP) and Stated Preference (SP) data. (KTH, 2011)

For major changes in supply, new travel forecasts give the best results. Demand elasticity can be sufficient for marginal changes in supply, where the period of time over which the changes occur is short that it can be assumed that other influencing factors are unchanged. Changes in price, journey time and other standard variables can be taken into account in separate models and combined to compute the net demand. Demand elasticity with respect to price (or 'price elasticity') is the relative amount of travel affected by a relative change in price. (KTH, 2011)

$$\text{Price elasticity of demand} = \frac{\Delta\ \text{travel/travel}}{\Delta\ \text{price/price}} = \frac{\text{change in travel (\%)}}{\text{change in price (\%)}}$$

Demand elasticities of less than 1 are inelastic, and values greater than 1 are elastic, implying a greater percentage increase in demand than change in supply. Travel time elasticities vary between -0.5 and -2.0 (or sometimes greater) depending on how critical travelling time is in terms of accessibility, competing travel modes and whether travellers are new to rail (Fröidh, 2012). 'Green Train' lists international examples of demand elasticities for train supply, the relevant factors of which are reproduced in Table 2.1.

Table 2.1: Examples of demand elasticities for train supply from 'Green Train'
Source: Fröidh (2012)

Supply factors	Interval	Elasticity	Source
Travelling time	Travelling time 2-4 hrs (peak at 2.5-3 hrs travelling time where competition from air exists)	–1.5 to –2.0	Nelldal, 2005b
	Model-calculated for high-speed trains in Spain	–2.4 to –2.6	Bel, 1997; Martín & Nombela, 2007
	Travelling time approx. 1 h on long-distance regional journeys on the Svealand Line	–1.7 to –2.4	Fröidh, 2003
	Sweden, distance dependent, primary competition from car Mean journey length 600 km 400 km 200 km	 –1.7 to –1.9[1] –1.0 to –1.1[1] –0.4 to –0.5[1]	Calculation guide, 2009
	IC trains in Great Britain 1996	-0.9	Seabright, 2003 (Wardman)
	IC trains in Great Britain 1991	–0.6 to –0.7	Seabright, 2003 (Macket & Nash)
Frequency of service	Sweden, ASEK 4 (in general)	0.5	Calculation guide, 2009
	10-20% change in frequency of service, Great Britain	0.3 to 0.4	DfT National Traffic Model (2002)
[1]Depending on distribution between private and business journeys			

The elasticities used in the 'Green Train' project are given in Table 2.2; they are based on the assumption that new travellers come mainly from car (rather than from air travel). Where there is a need to change trains, an empiric frequency of service elasticity of –0.2 is used, i.e. changing reduces elasticity by 20% (Fröidh, 2012).

Table 2.2: Demand elasticity in calculations for Gröna Tåget
Source: Fröidh (2012)

Supply factors	Elasticity	Interval
Journey time	-1.5 -0.9	2-4 h travelling time by fast train Other express train markets
Frequency of service	0.3 0.4 0.5	Up to 10% change 10-30% change Over 30% change

2.2.2 Comparative case: Svealand line

There are few studies on the effects of 'regional high-speed rail' (refer to 2.1) compared to interregional (classic) high-speed. The progressive introduction of regional high-speed rail services in the Stockholm-Mälaren region is documented to a limited extent, the most comprehensive of which concerns the Svealand line introduced in 1997. A summary of the effects makes up section 4.3.2 of this thesis but overall can be summarised as a seven-fold increase in travel demand and the retention of 30% of the regional transport market (Fröidh, 2003).

2.3 High-speed rail and regional development

2.3.1 Improved transport and regional development

The impact of transport on regional development is closely linked to the role of transport on economic development. Improvements to transport systems impact positively on firms by increasing the efficiency with which to source materials and deliver products (product market effects) and widening firms' access to a labour supply and reducing the costs of that access (labour market effects). These two effects increase the efficiency and market effectiveness of existing firms, leading to an expansion of output and employment; they also affect location behaviour of firms, attracting investment to regions of increased accessibility. (Goodbody, 2003; Rodrigue, J-P et al., 2009) The process is depicted schematically in Figure 2.8.

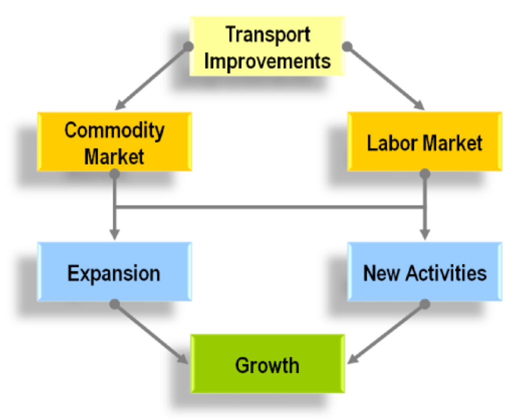


Figure 2.8: Transport impacts
Source: Rodrigue, J-P et al. (2009)

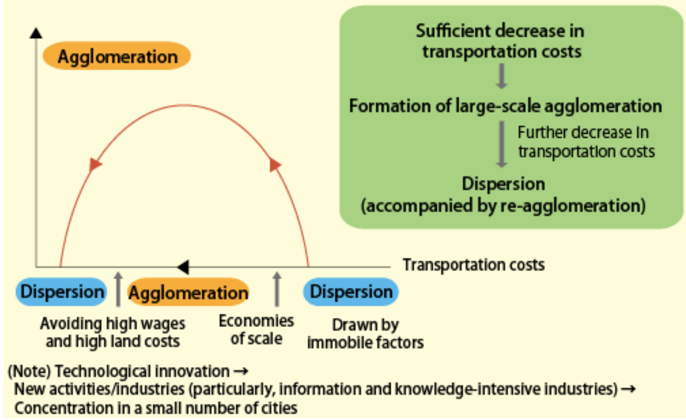


Figure 2.9: Transport costs on agglomeration
Source: RIETI (2011)

Product market effects

The cost savings to firms of improved transport can be considerable when counting both the direct costs of transport (which are typically around 5-10% of product costs) and the indirect effects on business costs (logistics chain improvements); since transport is an economic factor of production of goods and services, relatively small changes can have substantial impacts in on costs, locations and performance (Goodbody, 2003; Rodrigue, J-P et al., 2009). Further, improvements in transport favour geographic specialisation which increases productivity and spatial interactions through comparative advantages; they also support large scale production, increased competition and increased land value.

Besides the direct benefits to individual firms, growing economic opinion supports the notion that transport improvements generate positive spillover effects to the industry as a whole that result from externalities (e.g. knowledge spillovers and pecuniary effects) in an environment of imperfect competition where economies of scale exist. Quality of transport influences the location decisions of firms and the development of clusters (agglomeration); improvements to transport generate welfare gains through better exploitation of comparative advantage between regions, despite some experiencing real income loss as industry relocates. (Goodbody, 2003)

The reduction of transport costs has two effects: it causes production to be located to where it is cheapest and transporting goods to all markets from there; it also facilitates concentration of production in one location to obtain economies of scale. Hence there is a trade off between cheaper production costs at the periphery (wages, land) and larger markets and economies of scale at the core, which is dependent on transport costs. The effect of transport improvements on reducing inequities between the core and periphery depends on the initial level of transport costs: from a position of high transport costs, reduction leads to agglomeration at the core and increased regional inequalities, as economies of scale overcome initially prohibitive transport costs; a further reduction leads to dispersion of activities toward the periphery and a reduction in inequality, as the cost of transporting goods outweighs the benefits of scale economies at the core and firms seek to avoid higher labour and land costs. (Goodbody, 2003; Rieti, 2011) The U-shaped relationship is depicted graphically in Figure 2.9. Since the turning point of the 'U' is believed to occur at a higher level of transport costs than seen in typical inter-regional transport, regional inequalities are likely to be reduced by transport improvements.

Diseconomies of scale can also occur when economies of scale dominate transport costs, and reduced transport costs lead to a greater concentration of activity at the core until saturation, at which point dispersion occurs as firms move to the periphery. Diseconomies of scale are associated with external costs of congestion and environmental degradation; the diseconomies associated with car use and lower density suburban sprawl are shown to reduce the economic performance of cities compared to those with balanced transport systems and less dispersed land use (Goodbody, 2003; Newman, 2000). Where considerable diseconomies of scale exist, further improvements in transport are likely to benefit peripheral regions.

In a three-region network (one core and two peripheral regions) in which links between the two peripheral regions and core are improved, both peripheral regions are likely to experience welfare gains at the expense of the central region; further, the overall improvement is greater than the sum of improvements from each individual link due to the effect of an enlarged total market, a property known as 'super-additivity'. Where links between two peripheral regions are improved, their combined welfare is increased relative to the core. (Goodbody, 2003)

Labour market effects

Transport improvements reduce commuting journey times, leading to impacts on wage levels, availability of labour and the price of land/housing, which in turn affect the production and location decisions of firms. Reduced commuting costs elicit two complementary streams of response: commuting and migration (Pearson and Lee, 1993; from Goodbody, 2003).

A commuting response to increased accessibility due to transport improvements causes labour markets to increase in size and efficiency; workers can access a greater number of jobs over a larger area by commuting longer distances at the same cost, which can lead to lower wages, lower unit output costs, increased employment and better matching of skills with jobs. The regional distribution of the gains depends on the relative characteristics of workers and jobs in core and peripheral regions: workers from poorer peripheral regions may commute to jobs in the core region, expanding output there and increasing incomes in the peripheral region but with no creation of new economic activity; on the other hand, the creation of a larger regional labour market benefits industry in the region as a whole, which is reflected in increased inter-town commuting and relative economic success for towns/cities that are able to exploit their comparative advantage. (Goodbody, 2003)

A migration response to improved transport has varying effects on the housing market in less developed regions. Lower commuting costs may prompt workers employed in other regions to migrate to the less developed region on account of lower house prices or improved living standards; in this case, increased local labour supply may force wages down and house prices up, without necessarily improving regional welfare. Alternatively, it may encourage residents living in the region to move outside it and commute longer distances in order to benefit from lower house prices. (Goodbody, 2003)

Transport and land use interaction

The interaction of transport and regional development can also be represented by the land use transport feedback cycle, depicted in Figure 2.10, which arises out of the recognition that trip and location decisions co-determine each other. The dynamics of urban and regional change is complicated by different temporal rates of its components; land use and transport networks are slow to change but their associated movements can change and adapt quickly (Rodrigue, J-P et al., 2009). The pace of change with regard to different components is outlined below.

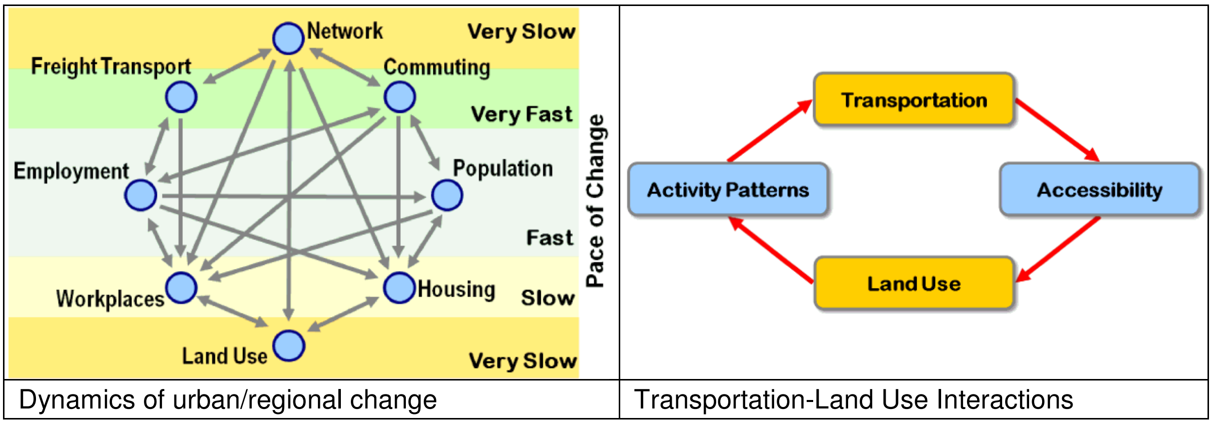


Figure 2.10: The land use transport feedback cycle
Source: Rodrigue, J-P et al. (2009) adapted from Wegener, M. (1995) "Current and Future Land Use Models"

Very slow change: transport networks (physical infrastructure), land use.

Slow changes: workplaces, housing; buildings exist longer than occupying residents or firms.

Fast change: employment, population; establishment/relocation of firms affects employment, which in turn is reflected in housing location and population distribution.

Immediate change: commuting, goods transport, travel; based on location of human activities.

2.3.2 Impact of high-speed rail on regional development

The impact of high-speed rail on regional development has been a subject of much discussion and there are varying opinions and evidence on whether high-speed rail contributes positively or negatively to the development of regions. The basic rationale is that improved accessibility due to high-speed rail enlarges labour markets (creating a larger pool for employers and more work opportunities for citizens), thus increasing the competitiveness and productivity of firms in newly connected areas and attracting new activities and residents; and offers firms wider location choices in favour of peripheral areas while benefiting from positive agglomeration effects. While there is a theoretical basis and some evidence in support of regions benefiting from a high-speed rail connection, the literature is cautious in promoting potential benefits universally; this is taken in the light of impact studies revealing modest improvements in economic performance (which are further complicated by the presence of external factors) and competing economic theory suggesting transport improvements reinforce the dominance of core regions over the periphery. (Preston et al, 2006; Knox, 2006)

It has been an objective of investment in high-speed rail and other transport infrastructures to reduce regional inequalities (De Rus, 2008); transport investments constitute a large share of structural and cohesion funds as part of the European Union Regional policy (EU, 2006). In most (if not all) cases however, high-speed rail projects have been planned and implemented with regional development treated as a secondary benefit. The primary aim has been to link the major cities (and their regions) that constitute the predominant inter-regional 'endpoint' market for the purpose of increasing accessibility (i.e. transport-related effects) to passengers and reducing the market share of competing modes; less consideration was given to smaller intermediate cities whose proximity to a high-speed line determined whether it received a connection and where the station was located (Ureña and Coronado, 2009). The literature is reflective of this traditional pattern of development of high-speed lines, addressing mainly the regional effects on major centres and only occasionally intermediate smaller centres served as a consequence of their connection to a line. It is therefore not entirely representative of a situation that would be termed 'regional high-speed'.

Several important conclusions on the effects of the introduction of high-speed rail on regional development can be drawn from the literature, which are subsequently elaborated:

- Theory suggests regions connected by high-speed rail will experience economic growth;
- Improved accessibility may cause economic activity to concentrate in large cities, serving to widen rather than narrow regional disparities;
- Impact studies report generally positive growth in economic activity, population and jobs in regions connected by high-speed but the effects may be redistributive and not net gain;
- Cities with a strong knowledge-based services sector have the highest growth potential;
- High-speed rail alone does not necessarily lead to regional development; complementary measures and supporting strategies are required;
- Centrally located stations attract more travellers and development than peripheral stations;
- Alternative transport investments, such as improving regional inter-city links may make a larger contribution to regional rebalancing that classic high-speed.

Theory suggests regions connected by high-speed rail will experience economic growth

The contribution of high speed rail to regional economic growth is based on the theory that, in the short term, time savings to travellers results in a direct increase in productivity and, in the longer term, increased accessibility brought about by high-speed enlarges market areas, increases the competitiveness and productivity of firms in newly connected areas and attracts new economic activities, residents and visitors (Vickerman and Ulied, 2009: 89-90); positive effects include the expansion of labour markets, the opening up of more competitive land and agglomeration economies for firms (Preston et al, 2006). Improved accessibility may also integrate formerly separated labour markets into one functional region (Knox, 2006; Blum et al, 1997; Kamel and Matthewman, 2008).

Recent theoretical work in 'new economic geography' helps to explain the impact of transport improvements on regional development. Firms make their location decisions based on a trade off between transport costs and external economies of scale (scale economies in intermediate outputs, labour market pooling, knowledge spillovers) arising in an environment of imperfect competition characterised by the geographical concentration of economic activity (known as 'agglomeration') (Tomaney, 2011; Brakman et al, 2009). Improved accessibility extends a firm's reach to wider markets, increasing productivity and generating positive agglomeration effects. Falling transport costs may make it attractive for firms to relocate to the periphery to avail of lower land rents/prices and supply larger markets from distance: a 'dispersion' effect. De Rus (2008) acknowledges there are some ambiguities related to the role of opposite forces which affect the balance between agglomeration and dispersion (regarding location).

Positive economic effects of high-speed rail may be more distributive than generative: limited to local movements within a region and toward high-speed stations (Kamel and Matthewman, 2008) or reinforce ongoing processes and facilitate intra-organisation trips in firms for whom mobility is essential (Albalate and Bel, 2010), but not generating new economic activity.

Improved accessibility due to high-speed rail may cause economic activity to concentrate in large cities, serving to widen rather than narrow regional disparities

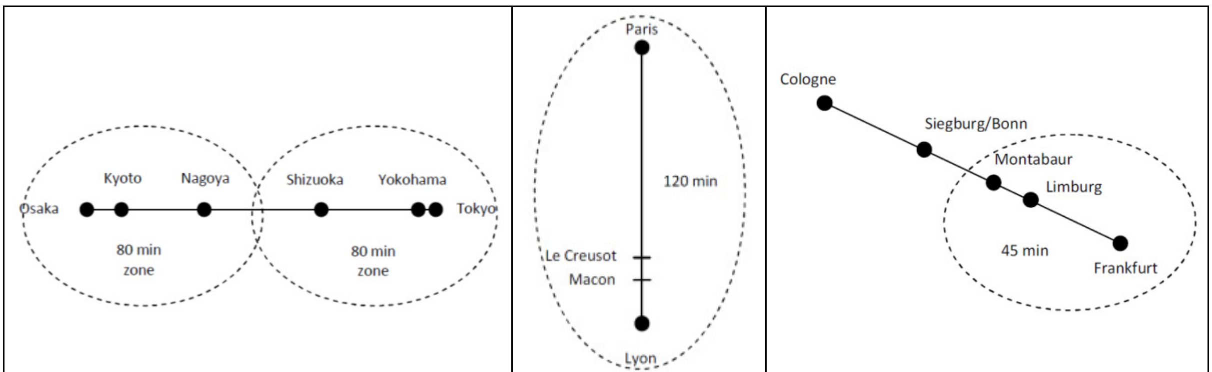
The majority of literature supports the principle that improved accessibility enabled by high-speed rail links may cause economic activities to concentrate in economically stronger regions (major cities) at the expense of weaker regions (smaller intermediate cities), thus widening regional inequalities. (Albalate and Bel, 2010; Tomaney, 2011; Puga, 2008; Palanza, 1998; Knox, 2006; Pol, 2003; De Rus, 2008; Vickerman and Ulied, 2009) Cities that already hold a strong competitive position have a relatively high economic potential and attractive location factors for new service companies and well-educated residents; these advantages will be enhanced by improved external accessibility (Pol, 2003). The dominance of large cities is also explained by the relative gains in accessibility between regions: the development of the European high-speed rail network has tended to increase the accessibility of core cities to a greater extent than peripheral regions (Tomaney, 2011); economic activities tend to converge towards the more accessible and better-equipped centres (Palanza, 1998).

The new economic geography theory explains the competitive advantage stronger areas have over weaker ones in an environment of imperfect competition and reduced transport barriers: positive externalities generated by agglomeration economies (that outweigh reduced transport costs) raise the productivity differential of the core city relative to the peripheral regions; thus firms in core cities have a comparative advantage over those in peripheral regions (Tomaney, 2011; Vickerman, 2009). Improved transport links between regions with different levels of development provide less developed regions with better access to the inputs and markets of more developed regions but also enable firms in the richer regions to supply poorer regions at a distance, harming industrial growth prospects of less developed regions (Puga, 2002).

Albalate and Bel (2010) suggest medium size cities might suffer the most from the economic attraction of larger more dynamic cities. Cities with a high-speed connection may gain some benefits but these may be at the expense of neighbouring areas, particularly if intra-regional links are poor, thus exacerbating disparities in development within a region (Tomaney, 2011; Palanza, 1998). These are however not universal or inevitable outcomes and depend on the specific regional situation, initial levels of accessibility (and their change) and other policy measures accompanying the transport improvement (Vickerman, 2009). Pol (2003) considers the advent of high-speed rail as an opportunity for weaker regions to enhance their economic potential and location factors, subject to these exceeding a minimum critical level.

Impact studies report generally positive growth in economic activity, population and jobs in regions connected by high-speed but the effects may be redistributive and not net gain

Melibaeva et al (2010) present a comparative review study of transport and regional development effects of high-speed rail in three ‘megaregion’ corridors: Japan (Tokyo-Osaka), France (Paris-Lyon), and Germany (Frankfurt-Cologne); these are densely populated corridors with intermediate stops in the commuter belt of larger cities in which high-speed rail has had the effect of either creating or enhancing a unified economic “megaregion” agglomeration. While the focus of regional high-speed rail is different (rather to link discrete medium-sized regional cities and the capital in less dense non-contiguous -urban corridors), economic development and spatial effects are partially applicable and interesting to observe.



Tokyo-Osaka corridor	Paris-Lyon	Frankfurt-Cologne corridor

Figure 2.11: High-speed rail ‘megaregion’ corridors (Source: Melibaeva et al, 2010)

Tokyo-Osaka (Tokaido) Shinkansen corridor (Japan)

The high-speed link has favoured cities specialised in information exchange industries (such as banking services, real estate, R&D, education, and political institutes), mainly Tokyo and Osaka, which have experienced strong employment growth since high-speed was introduced; interaction between cities with a tourism and services focus increased, driven by growth from neighbouring cities. The link contributed to further centralisation of economic activity in the metropolitan areas around Tokyo and Osaka; the manufacturing city of Nagoya experienced a decrease in employment, reflecting the limited benefit of high-speed rail to this sector. Jobs growth occurred in urban areas along the corridor, although it is difficult to credit this solely to high-speed and/or if it is at the expense of non-connected regions. (Melibaeva et al, 2010)

Paris-Lyon TGV Sud-Est corridor (France)

The high-speed link reinforced the existing centralisation of economic activity in Paris, which was also able to increase services exchanged in Lyon's markets. Lyon benefitted by attracting several businesses, mainly from neighbouring cities within the Rhone-Alps region, and gained access to Paris's services market. The intermediate city of Macon experienced a small growth in businesses and employment, mainly due to businesses relocating from the Saône-et-Loire region rather than from Paris or Lyon; Le Creusot did not experience job or business growth. The connected regions have experienced a degree of economic development, reflected in high levels of rail trips, but this was mainly due to a redistribution of economic activity from non-connected cities to connected cities. (Melibaeva et al, 2010)

Cologne-Frankfurt ICE corridor (Germany)

The smaller intermediate cities of Montabaur and Limburg, previously without a conventional rail connection, were affected positively as a result of improved connectivity to Frankfurt and Cologne. Increased daily commuting from Montabaur and Limburg to Frankfurt was matched by residential population growth in the two smaller cities. The traffic increase from Siegburg to Cologne was low and more trips are taken in the direction of Frankfurt. Frankfurt benefitted over Cologne in attracting more commuters, which is explained by a larger labour market and services stock. Residences relocating from Frankfurt to Montabaur and Limburg do not count as new employment and growth but as relocated economic activity. (Melibaeva et al, 2010)

Other impact studies

The outcome of a recent UIC study on the effects of high-speed rail on regional development is described in section 2.3.3; it reports generally positive growth for high-speed linked cities. Other studies report modest impacts on economic performance: 1-3% of GDP (Preston et al, 2006); faster population, job and economic growth for cities on high-speed routes that those bypassed (Chen and Hall, 2009); increase in commercial activity and land values in excess of 50% near high-speed stations (Preston et al, 2006); and marginal increases in population and housing growth in regions benefiting from a high-speed link (Albalate and Bel, 2010). Most studies agree that cities/towns with a high-speed connection regard the connection as positive and an improvement on the location's attractiveness although the benefits are hard to isolate.

Cities with a strong knowledge-based services sector have a higher growth potential than cities based on traditional agricultural and industrial sectors

Several literature sources suggest that cities with economic sectors that are heavily geared to services and high-technology ‘knowledge industries’ are more likely to gain from high-speed rail than those built on traditional sectors of agriculture and manufacturing (Albalate and Bel, 2010; Chen and Hall, 2009; Melibaeva, Sussman and Dunn, 2010; Greengauge21, 2006; Knox, 2006). Chen and Hall (2009) note increased growth rates in population and economic effects for cities on high-speed routes are largely concentrated in knowledge-intensive sectors and tourism-related activities. It is suggested that as freight transport does not usually benefit from high-speed, the location of industry is not likely to be affected by it (Du Rus, 2008).

High-speed rail is most appealing to higher income groups and businesses that place a high value on time, with a high level of interaction with other businesses and which are located in city centres due to agglomeration externalities (Tomaney, 2011; Knox, 2006). High-speed travel thus involves much business related movement by executives and specialists, but also includes some commuting, mainly over short distances to major cities, and leisure travel over longer distances; the focus is evidently on service sectors of the economy: business, public administration, leisure, commerce, and tourism. Economic activities that lie in these fields benefit most from high-speed rail and positive effects will follow in cities for which it serves a growing services sector. Gains are predicted in cities that are either already heavily oriented towards service sector (such as Lyon, Zaragoza, Cologne or Milan) or committed to moving in that direction (such as Lille or Cordoba) (Greengauge21, 2006). In France, Le Mans successfully shifted to a high-tech industry base and Lille became a transport hub (Shin et al, 2005).

High-speed rail alone does not necessarily lead to regional development; complementary measures and supporting strategies are required.

Theoretical reasons and observed impacts lead to the conclusion that high-speed rail alone is not a guarantor of regional development and must be supported by complementary measures. Several sources insist on the need for supportive planning policies and stimulus measures to realise the positive economic effects of high-speed and contribute to the reduction of regional disparities (Palanza, 1998; TCPA, 2011; Shin et al, 2005; Preston et al, 2006; Goodbody, 2003; Chen and Hall, 2009; Tomaney 2011). TCPA (2011), in its consultation on high-speed rail in the UK, advocates measures improving the link between transport, land use and spatial planning to support local and regional economic regeneration. Chen and Hall (2009) refer to office decentralisation policies in the UK in the 1960s and 1970s to relocate activities across British regions as a means of capturing development opportunities. High-speed rail might also build on strategies aimed at linking cities together to create expanded functional corridors with improved intra-regional accessibility that can compete more effectively with larger cities (Knox, 2006; Blum et al, 1997). Greengauge21 (2009) maintains that high-speed rail must relate to the activity patterns and developments in cities served to be a positive influence on the local economies. It proposes a broad set of complementary measures set out in Table 2.3.

Table 2.3: Summary of complementary measures for high-speed rail
Source: Greengauge21 (2009: 24) with minor modifications

HSR = high-speed rail	**Top down (national/state)**	**Bottom up (regional)**
1. HSR configuration		
1.1 Parkway vs central HSR stations	• Identify centres for which direct access is a 'must' in terms of regional economic benefit	• Identify feasible options, costs, sources of finance and balance of economic and transport advantages
1.2 Inter-regional vs region-core links	• Prioritise intra-regional links to each other and to core city	
2. Other related transport		
2.1 Extending benefits through local links to HSR	• Developing evaluation/ appraisal tool for local transport investment • Developing regional airports	• Identify business and labour market segments likely to benefit, and how
3. Non-transport actions		
3.1 Economic specialisation	• Develop the role of regional corridors as a counterbalance to larger core cities	• Identify sectors within regions for which advantage through HSR exists or could be created • Identify potential for beneficial relationships between sectors in sub-regions, and means for amplifying accessibility benefit
3.2 Governance	• Nat. responsibility for strategic economic and spatial context • Devolution to regional bodies	• More joined up local action, taking advantage of devolution
3.3 Appraisal	• Transport appraisal to include national value of longer-term changes in regional economic disparities and population shift • Combine appraisal of HSR and complementary measures	

Station location and intra-regional transport

Impact studies consistently report that stations located in a city centre attract more travellers and development than peripheral ('green-field') stations outside the city (Martinez et al 2010; Melibaeva, Sussman and Dunn, 2010; Tomaney, 2011; Albalate and Bel, 2010); however, it may have to do more with an absence of multimodal connections linking the station to other parts of the city and a lack of a surrounding dynamic economic area than purely location.

Tomaney (2011) suggests that alternative transport investments, such as improving regional inter-city connections, may make a larger contribution to regional rebalancing that classic high-speed. Further, smaller-scale local infrastructure projects that improve communications within a less favoured region can have a positive regional impact (Albalate and Bel, 2010). Steer Davies Gleave (2004) remark the existence of very good conventional rail lines reduces the incremental economic case for high speed rail, particularly over shorter distances.

To summarise the discussion on the effects of high-speed rail on regional development: there are positive effects to be expected but to be regionally balanced requires supportive measures and favourable economic conditions; effects are generally distributive rather than generative. Intra-regional transport improvements may be more beneficial than long-distance high-speed; the implication is towards 'regional high-speed rail' and other regional transport investments.

2.3.3 Assessing the longer-term regional effects of high-speed rail

The medium-long term (spatial-economic) regional impacts of high-speed rail are assessed by observing different demographic, economic and physical indicators, which are interdependent and cross-influencing (DB, 2011). Typical indicators are described hereunder.

Population
The number of inhabitants in a particular city and/or extended area is assumed to increase following the introduction of high-speed rail, brought about by increased city attractiveness, reduction in travelling time and travel cost, increase in economic activity and the opportunity for new locally-sourced jobs. The extent of commuting (enabled through reduced travel time permitting longer distances to be travelled each day) determines the degree to which cities are "sleeping (or bedroom) cities" or "working cities".

Commuters
Commuting can become feasible if travel time is improved to the extent that daily journey time to a workplace in another city is reduced to within one hour. There may be financial and quality of life benefits to moving to a smaller city and commuting daily or occasionally to the major city. Effects are measured as the share of or absolute number of high-speed commuters between cities or regions.

Students
The change in number of students is relevant in cities or regions with universities. Students may be viewed as commuters with a special trip purpose, in contrast to (but alike) commuters making a business trip. The reduction in travel time enables universities to extend their commuting area for students.

Gross Domestic Project (GDP)
GDP measures the economic strength of defined area such as a city, region or country. An increase in local economic activity could lead to an increase in economic power measured by GDP but small changes in the local economy might be difficult to distinguish.

Unemployment / Employment
Unemployment reflects the economic performance of a city or region and may correlate with the level of commuting based on the economic development of adjoining regions.

Surrounding area of a station
Changes in the surrounding area of a station are often the most visible short-term effects of the introduction of a high-speed rail connection to a city. The type and location of the station is important: a new station on a greenfield site has more development potential due to lack of space restrictions, whereas a station in a city centre in an existing structure is restricted in size and scope by a historical city centre despite having better accessibility.

Real Estate / Land prices
Changes in real estate and land prices over time reflect the pace of development and demand for space, although early speculative price rises are considered short-term temporary effects.

Land use
Changes in land use reflect new demands for space and the movement of economic activity from one sector to another, such as from agriculture to industry or industry to services.

The International Union of Railways (UIC) commissioned a study on the effects of high-speed rail on regional development titled "High Speed Rail as a tool for regional development - In-depth Study" (DB, 2011). The study examines the medium-long-term impacts on cities on the high-speed networks of five countries (Japan, France, Germany, Italy and Spain) using both qualitative and quantitative analyses based on indicators described above. The impacts studied include changes in population, economy and tourism and changes in the surrounding areas. To isolate the effects of high-speed rail (HSR) from other factors, HSR cities were paired with non-HSR cities of similar nature and compared using time series.

The qualitative analysis deals exclusively with changes to the surrounding area of the station over a ten year period, which is generally the first and most visible impact from HSR and an indicator of potential changes to occur in a wider area (DB, 2011). The results reveal a degree of development in all HSR cities where space permits but which occurred after the opening of the station. The analysis also determined that the differences in level of development depend on the following framework conditions: direct access to motorway, commuter distance to the next metropolis, short distance to city centre, available areas for development, existing basis for development in surrounding area (city size, economic power etc.), service level, station as a transport hub, and political willingness / cooperation of various institutions.

The quantitative analysis deals with population and economic changes over an eight year period, which represent the longer term more permanent regional development effects. The varied results show that HSR cities have achieved a higher level of development than non-HSR cities. Comparing countries, Germany experienced a good level of development with HSR (examples: Wolfsburg and Fulda) and there are positive examples in Japan, particularly in population growth. In France, several HSR cities achieved a higher level of development than non-HSR cities, while samples in Spain and Italy did not indicate significant overall differences between the city pairs. The study also found a positive relationship between city size and travel time to the next important city, and the level of development. This supports Vickerman's (2009) theory of a positive relationship between city size and productivity.

2.4 Polycentric regional development

2.4.1 Complementary polycentrism and city networks

Regional development is consistent with a polycentric city structure, and polycentric policies have been employed in the European Union to achieve balanced regional development, reduce regional disparities, improve competitiveness and promote sustainable development (ESPON, 2005). Transport investments that increase accessibility and interaction between cities and regions, including regional high-speed rail, play an important role in achieving those ends.

Polycentrism is an empirical concept that stems from central place theory, a geographical theory that seeks to explain the number, size and location of human settlements in an urban system (Goodall, 1987). At a regional level, polycentricity is characterised by several cities at different levels with equal opportunities for interaction rather than being dominated by one city; it contrasts with monocentricity, in which service provision and territorial management competence is increasingly concentrated to a single centre. It is also opposed to urban sprawl, in which the structure of secondary centres is diluted in a 'spatially unstructured continuum'.

Polycentrism emphasises urban complementarities, whereby two or more cities complement each other functionally by combining their existing assets to provide residents and businesses access to urban functions normally only offered by large cities. Polycentric development runs parallel to the development of specialist regional competencies, where synergy and strength are pursued and developed through regional networks of specialists, suppliers, specialised education and labour markets (ESPON, 2005:4; Meijers 2004).

The socio-economic benefits of a (complementary) polycentric urban structure are improved urban competiveness, increased regional cohesion and the diminishing of urban disparities as regards population development, economic development, employment, GDP and provision of services (ESPON 111 WP2: 2, 2005). It is characterised by a functional division of labour, an important precondition for economic development of regions, which is strengthened as small-medium-sized cities specialise in specific functions for an entire region and build their own identities. Further, resisting the tendency towards a monocentric structure reduces challenges faced by large urban areas in terms of welfare issues, such as traffic congestion and crime.

The environmental benefits linked with polycentricism relate to spatial planning and quantity of travel (Newton, 1997). Transport infrastructure improves links between urban centres and reduces travel time between them. Spatial planning that distributes populations around small and medium cities rather than around already large urban areas (increasing urban sprawl) means less commuting time and distance to city centres and greater availability of recreation areas (ESPON 2005: 228). A reduction in (predominantly car) travel reduces CO_2 emissions, pollution, noise, congestion and other adverse effects on the natural environment.

Blum et al (1997) propose high-speed rail as a way of linking together many cities to create a new type of region or corridor with high interregional accessibility; a 'band of cities' is transformed into an extended functional region or 'corridor economy', integrating labour markets and markets for services and inducing a relocation of households and firms within corridors.

2.4.2 High-speed rail and polycentric regional development: Catalonia, Spain

Regional high-speed rail development in the Catalonia region of Spain has been related to the configuration of a more polycentric region made up of several distinct but interacting medium sized cities facing economic specialisation and local development strategies brought to within an hour of Barcelona. Avoiding deterministic relations between high-speed rail and territory, Feliu (2007) studies pre-existence trends, objective factors (resources in infrastructures and services) and the behaviour of territorial subjects to assess the effects of high-speed rail on linking together several cities and creating corridors of high interregional accessibility.

A shift has emerged in recent years in high-speed rail planning principles from direct linking of large cities over medium (300-600 km) distances to connecting medium-sized cities and large cities over distances of 100-200 km with high frequencies; it is reflected in examples in France (Le Mans-Paris; Dunkirk- Calais- Boulogne-Lille), Spain (Ciudad Real- Puertollano-Madrid) and Belgium (Aachen- Liège-Brussels). The Catalan region envisages services on a similar scale with a maximum travel time of 60 minutes to Barcelona and high frequencies. In the short-term, high-speed rail will enable growth in commuting, business and leisure travel between regional centres; in the medium-long term, increased accessibility and development of economic projects already underway will induce the relocation of households and firms in the region, enabling improved socio-economic integration of the Catalan cities. (Feliu, 2007)

High-speed rail is characterised as having a *catalysing* role: instigating change and renewal of local resources in poorer and further-away cities; or a *facilitating* role: improving the existing trends and developing existing poles and resources of well positioned cities. (Feliu, 2007)

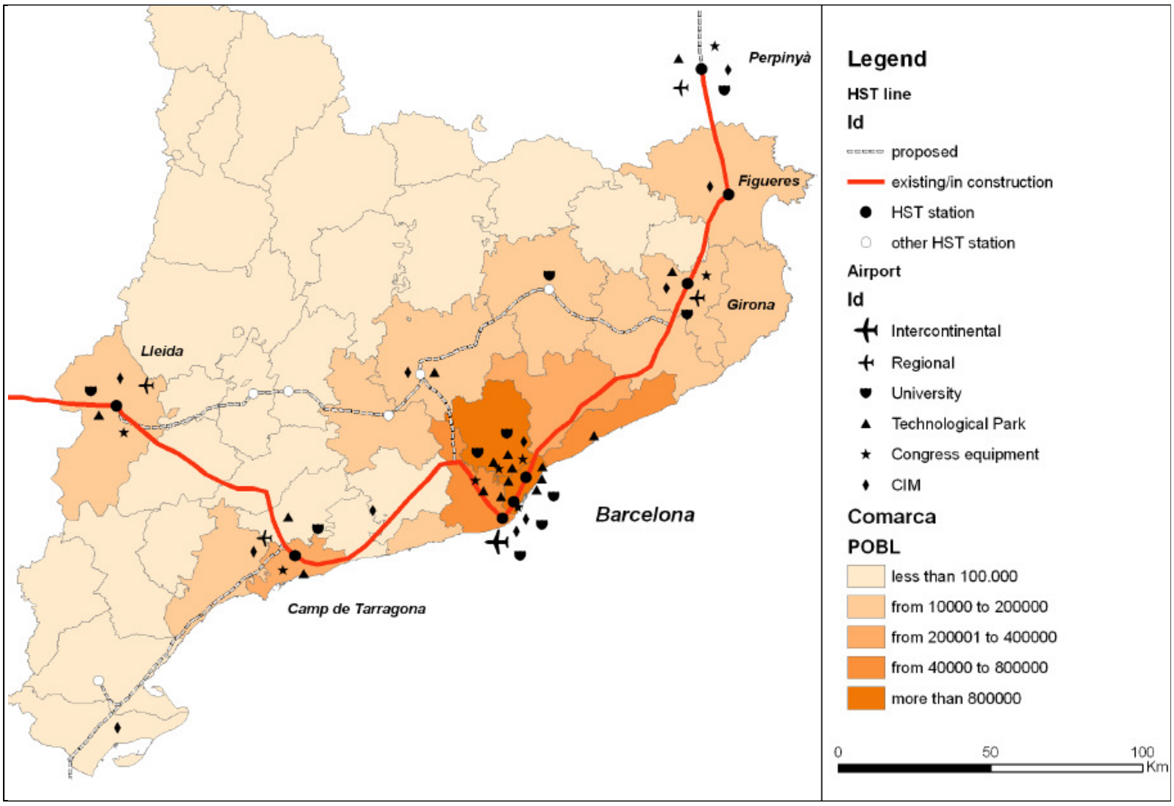


Figure 2.12: Infrastructures and planned high-speed rail in Catalonia (Source: Feliu, 2007)

3.1 Overall methodology

The overall approach of this study is to analyse the short-term travel behavioural and longer-term regional effects of the introduction of high-speed rail in the Stockholm-Mälaren region and, based on these results, investigate the possibilities for a regional high-speed rail network in Melbourne-regional Victoria as part of a regional development strategy. The approach is depicted in the figure below.

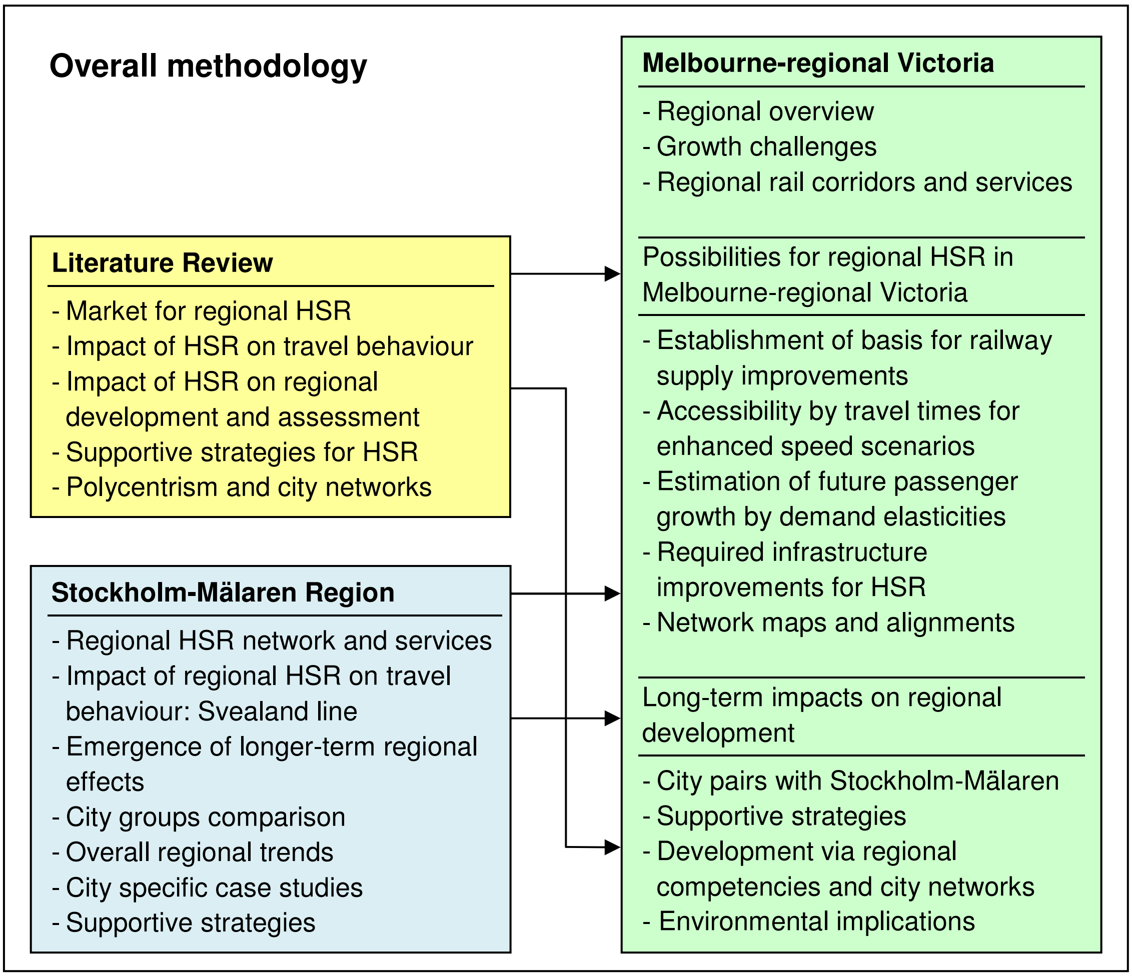


Figure 3.1: Overall study methodology

An overview of the methodology for the main sections of the study is given below. Specific methods employed for determination of travel times based on higher speeds and estimation of passenger growth by demand elasticities are covered in the subsequent sections. A summary of the results of the different sections, including concluding remarks, recommendations, study limitations and possibilities for future work form a chapter at the end of the report.

3.1.1 Regional high-speed rail in the Stockholm-Mälaren region

This section begins with an overview the high-speed rail network in the Stockholm-Mälaren region of Sweden, summarising the physical characteristics and services offered on each line. Line characteristics (maximum speed and track configuration) are sourced from Trafikverket and the KTH Railway Group. Services information (departure times, frequencies and travel times) is taken from online timetables and/or published travel statistics.

The next part considers the short-term effects of the introduction of high-speed services on the travel market and behaviour, with a focus on the previously studied Svealand line. Fröidh (2003) is used to summarise changes in travel behaviour, in terms of ridership, market share and extent of commuting. The emergence of longer-term regional effects (spatial changes) is then examined for a few lines based on a comparison between characteristically similar cities grouped according to population and distance from Stockholm; the effects are measured based on indicators (extent of commuting, population/job growth changes) in accordance with the literature and previous studies. A summary of overall trends for the region follows and three city case studies are undertaken to confirm (or otherwise) the emerging effects and learn what supportive strategies have been (and are being) undertaken to complement the rail services.

3.1.2 High-speed rail in Melbourne-regional Victoria

This section begins with a general overview of Melbourne-regional Victoria and the regional growth challenges faced; this is followed by an analysis of the regional rail network (including recent enhancements) and services provided. Line characteristics (maximum speeds and track configuration) are sourced from track manager and operator V/Line's online information and the rail resource website "vicsig.net". Services information (departure times, frequencies and travel times) is taken from published timetables.

Based on the analysis of the Stockholm-Mälaren region, enhancements are proposed to bring the Melbourne-regional Victoria network to true high-speed status with the aim of achieving significantly reduced travel times, particularly those acceptable for commuting. Accessibility is expressed graphically in journey time isochrones for different speed scenarios compared to existing or lesser speed outcomes. To reflect the different duties and traffics of the different lines, the network is divided between 'inner' regional lines, representing those lines between Melbourne and the large regional centres that already have a reasonable standard, and 'outer' regional lines, representing those lines that extend outward from the inner line termini to rural areas; different speed combinations are applied to the inner and outer line groups to assess the marginal affects of travel time improvements and identify efficient arrangements; increased service frequencies are also applied to outer lines to reflect higher speeds. Demand elasticities sourced from other studies are then applied to the various speed scenarios to estimate expected passenger growth which are compared to the Svealand line case. Finally, an overview of the infrastructure improvements required for true high-speed operation is described for each line according to the different target speeds. Upgrades are represented by network speed maps and approximate line alignments.

The next part theorises on the longer-term regional development impacts of the application of high-speed to Melbourne-regional Victoria using the Stockholm-Mälaren region as reference and indications from the literature. A comparative analysis pairs cities from the Stockholm-Mälaren region and Melbourne-regional Victoria that exhibit similar characteristics in terms of distance from the capital, population size and scale of the local economy. Reference cities are analysed in terms of regional effects based on the same indicators used in the Stockholm-Mälaren study (extent of commuting, population/job growth changes) to predict the long-term effects that might be expected in their regional-Victoria counterparts in a high-speed setting. The final section discusses and proposes supportive strategies for high-speed rail that could be enacted to assist in achieving the regional development objectives; they are proposed based on the Stockholm-Mälaren experience and literature sources.

3.2 Specific methods used

3.2.1 Determination of travel times for higher speeds

New travel times based on higher maximum line speeds are determined approximately based on average operating speeds derived empirically from published or timetabled travel times in respect of the maximum line speed. For each speed scenario, a representative average speed is determined that equates to an average speed/maximum (target) speed ratio; these empirically derived speed ratios are used to establish ratios for higher speeds for which base data does not exist. The average (operating) speed is the travel time to a station divided by the cumulative rail distance from the origin (or 'chainage'); new travel times are derived inversely.

It is not an overly accurate basis for calculating travel times, as average speeds will be lower for destinations closer to the major city (where stations are closer together and line speeds are lower) and greater for longer distance destinations (where stops are further apart and open space permits maximum speeds over a greater length); this tends to underestimate times for shorter trips and overestimate times for longer trips. Despite its limitations, it is a relatively simple means of estimating approximately the expected travel time gains resulting from the application of higher speeds. A more accurate depiction would require detailed alignments and the construction of speed profiles, which is beyond the scope of this thesis. The derivation of each target speed is described in detail in section 5.3.2.

3.2.2 Passenger growth by demand elasticities

Passenger growth factors for improved supply are estimated using demand elasticities, which are applicable for marginal changes in supply; the upgrade of existing lines to higher speeds is treated as a marginal change. They are applied to travel time gains and frequency increases. The elasticities used in the 'Green Train' project are used, which are based on the assumption that new travellers come mainly from car or are newly generated. Ticket prices and comfort level, which are assumed to be unchanged, are not included in the analysis.

Travel time

Travel times gains are separated into three time intervals, whose approximate elasticities are:

31-120 minutes: -0.9

121-240 minutes: -1.5

241-420 minutes: -0.9

The travel time change from current to new must be split into elasticity intervals according to aggregate travel time. For example, a reduction from 150 to 100 minutes would be separated into two intervals: from 150 to 121 minutes, i.e. -30 minutes or -30/150 = -20%, and from 120 minutes to 100 minutes, -17%. Elasticity -1.5 multiplied by -0.2 gives 30% more passengers, and -0.9 multiplied by -0.17 gives 15% more passengers; in total, 45% more passengers.

Travel time elasticities (in particular) are applicable to marginal changes in travel time, where up to 30% change may be considered as marginal. For longer journeys that exceed two hours, travel time reductions due to improved supply may exceed 30% and attract the greater middle band elasticity of -1.5; in such cases, demand may be overestimated and is only approximate.

Frequency

The frequency is the number of departures from first train in the morning to last train in the evening, excluding night trains. The approximate waiting time elasticities in intervals are:

1-10% change: -0.3

11-30% change: -0.4

31-100% change: -0.5

For example, a reduction in waiting time from 2 to 1.5 hours (120 to 90 minutes) represents a reduction of -30/120 = 25%; multiplied by elasticity -0.4 results in 10% more passengers.

Combined growth factor

The resultant growth factor for a travel time reduction and frequency increase is the product sum of the two. Using the examples above, the total growth factor is (1.45∗1.10 = 1.60), or 60% more passengers.

Higher elasticity for journeys of one hour

The Svealand line study (Fröidh, 2003) determined considerably higher elasticities of -1.7 to -2.4 (depending on the proportion of business and private travellers) for an approximate travel time of one hour on long-distance regional journeys on the Svealand line. As a separate case, the higher elasticity is applied on journeys achieving an approximate travelling time of one hour to observe the potentially higher growth effects. Assuming a roughly even proportion of business and private travellers, a mid-value of -2.0 seems appropriate to apply.

4.1 The Stockholm-Mälaren region: overview

The Stockholm-Mälaren Region (commonly referred to as the Mälaren Valley; Mälardalen in Swedish) comprises the Swedish capital of Stockholm and the region west of it surrounding Lake Mälaren. It is a polycentric region taking in a population of around 3 million, of which 2 million is in the greater Stockholm region; the largest regional centres have populations of between 65,000 and 140,000 and are situated between 65 and 150+ kilometres from the capital. The region is traditionally built on various primary and manufacturing industries, although in more recent times it has undergone a shift towards a knowledge-based services sector (Mälardalsrådet 2012). A map of the region is depicted in Figure 4.1 below.

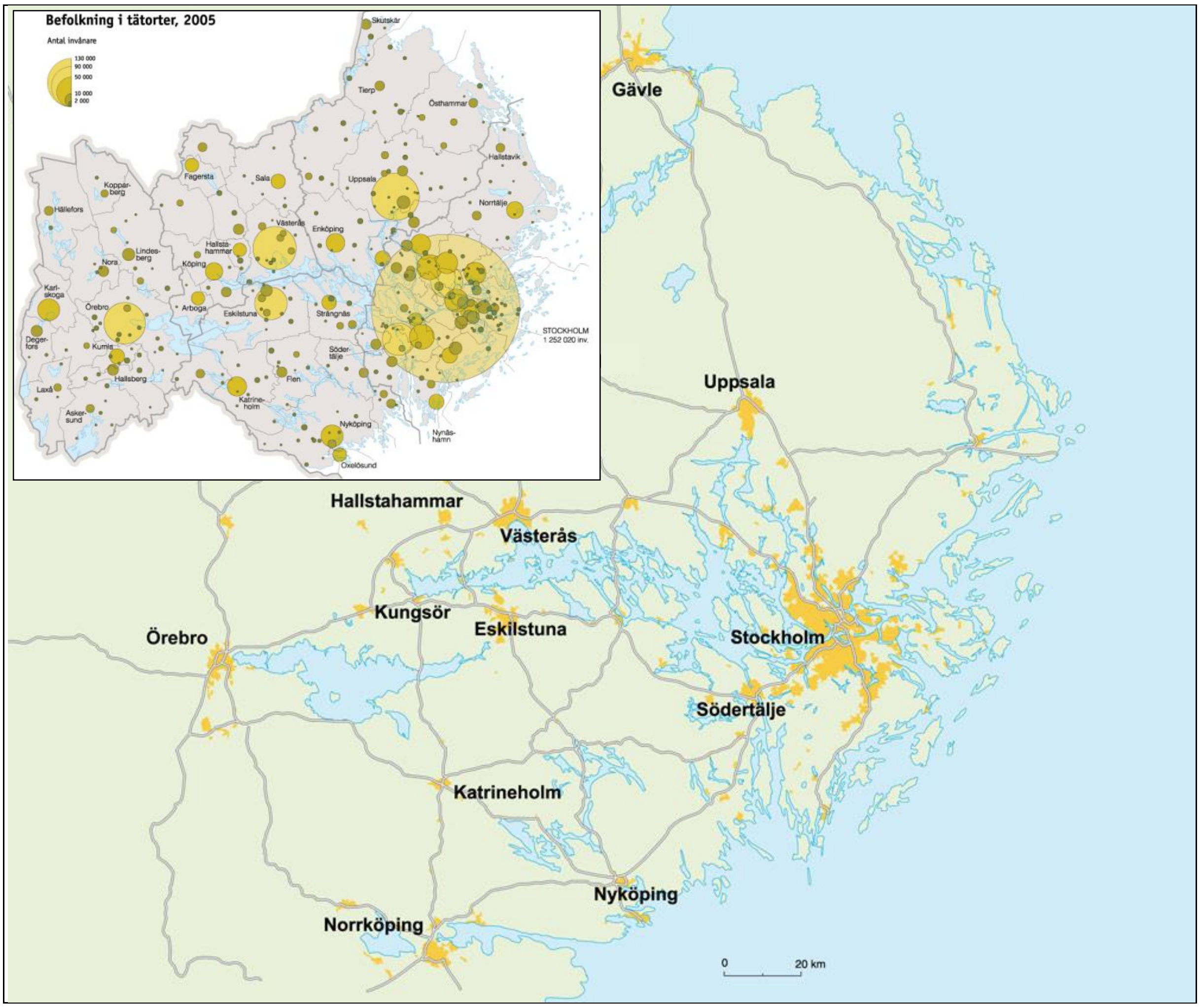


Figure 4.1: Stockholm-Mälaren region
Source: Mälardalens Limousineservice (www.malarlimo.se)

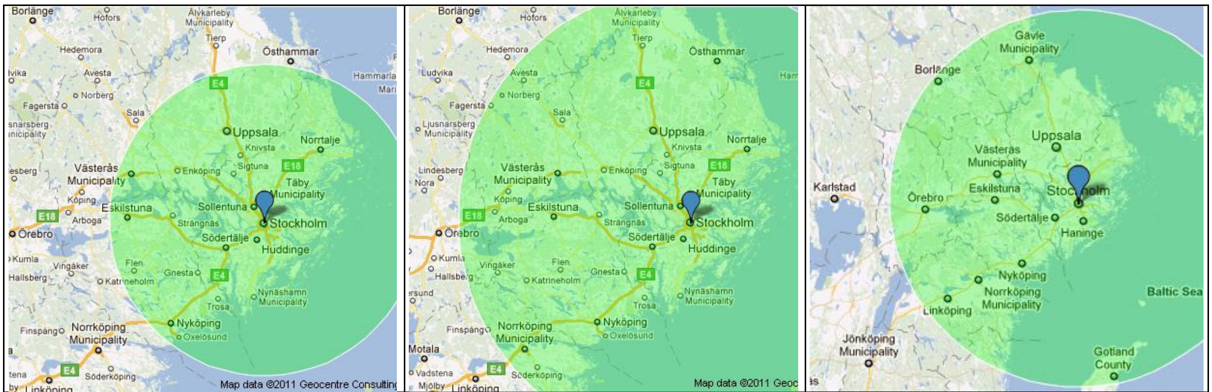
All significant regional centres are linked to Stockholm via motorways and regular regional high-speed rail services capable of up to 200 km/h operation, thus enabling good accessibility and fast commuting between centres.

Table 4.1 summarises population, distance from Stockholm and main economic sectors of the important cities in the Stockholm-Mälaren region. Distance given is ‘road distance’, which is considered the benchmark for travel time and accessibility. Figure 4.2 shows direct distance radii at 100, 150 and 200 km from Stockholm.

Table 4.1: Stockholm-Mälaren region: city population and distance from Stockholm
Sources: SCB (2012); www.freemaptools.com/; www.sna.se/webbatlasgis/; municipalities’ websites

City	Population		Dist from Sthlm (km)	Economic sectors
	City	Municipality		
Arboga	10,330	13,285	151	Hub, metal industries, aviation electronics
Enköping	21,121	39,759	80	Logistics, engineering, agricultural firms
Eskilstuna	64,679	96,311	112	Vehicle manufacturing, logistics, education
Hallstahammar	10,478	15,175	130	Metallurgy, automotive engineering
Gävle	71,033	95,055	175	Paper and packaging, logistics, GIS, radio
Katrineholm	21,993	32,428	143	Transport hub, logistics, graphics, farming
Köping	17,743	24,905	147	Manufacturing and processing, trade
Linköping	104,232	146,416	199	Aviation industries, trade, IT, health, ed.
Norrköping	87,247	130,050	162	Paper and packaging, logistics and transportation, electronics, IT, media
Nyköping	29,891	51,644	102	Commuting, airport, Oxelösund port
Örebro	107,038	135,460	196	Printing industries, advertising, logistics, education, health, government agencies
Stockholm	1,372,565	847,073	0	Services, telecommunications, IT
Strängnäs	12,856	32,419	89	Pharmaceutical, instruments, electronics
Södertälje	64,619	86,246	35	Manufacturing, pharmaceutical industries
Uppsala	140,454	197,787	72	Medical research, biotechnology, telecommunications, IT, trade
Västerås	110,877	137,207	110	Railway industries, electronics, IT, industrial automation, logistics

[1]Includes (surrounding) suburbs which form a “contiguous” built-up area (i.e. no satellites such as Södertälje)



100km from Stockholm | 150km from Stockholm | 200km from Stockholm

Figure 4.2: Distance radii from Stockholm
Source: Free Map Tools (Radius around Point) (2012)

4.2 Regional high-speed rail services

4.2.1 Railway network and infrastructure

Regional high-speed rail services in the Stockholm-Mälaren region are spread over a network of rail lines principally emanating from Stockholm. The network comprises regional rail lines of single or double track, which carry fast regional trains and some freight; and main line rail lines, which carry long-distance high-speed passenger trains (that also serve the regional rail market), freight and (to a lesser extent) local and regional trains. Figure 4.3 illustrates the rail network of the Mälardalen schematically (indicating lines and stations) and Figure 4.4 maps the infrastructure of the railway network, indicating line speeds, track configuration, passing stations and capacity enhancement measures. A brief description of two representative high-speed regional lines (Mälarbanan and Svealandsbanan) is given in Figure 4.5.

All lines have a maximum permitted speed of 200 km/h, with the exception of the Sala-Flen-Oxelösund cross line which is limited to 140 km/h and the Nyköping line between Järna and Åby (north Norrköping) which is limited to 120-160 km/h. Furthermore, all lines carry both passenger and freight traffic, are electrified and are equipped with Automatic Train Control (ATC). (Trafikverket, 2012; järnväg.net, 2012)

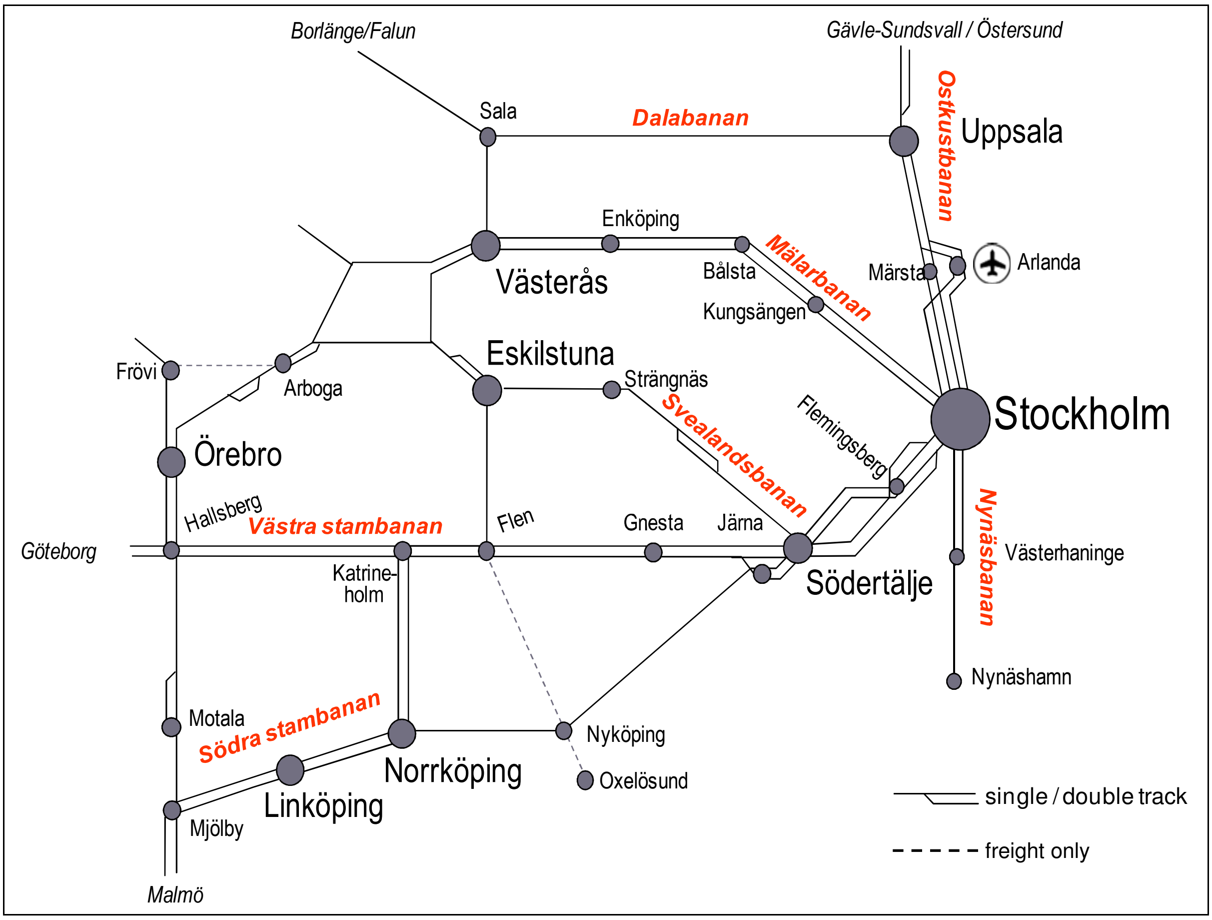


Figure 4.3: Mälardalen rail network

Source: Marknadsundersökning för tågtrafik i Mälardalen (Fröidh, 2003)

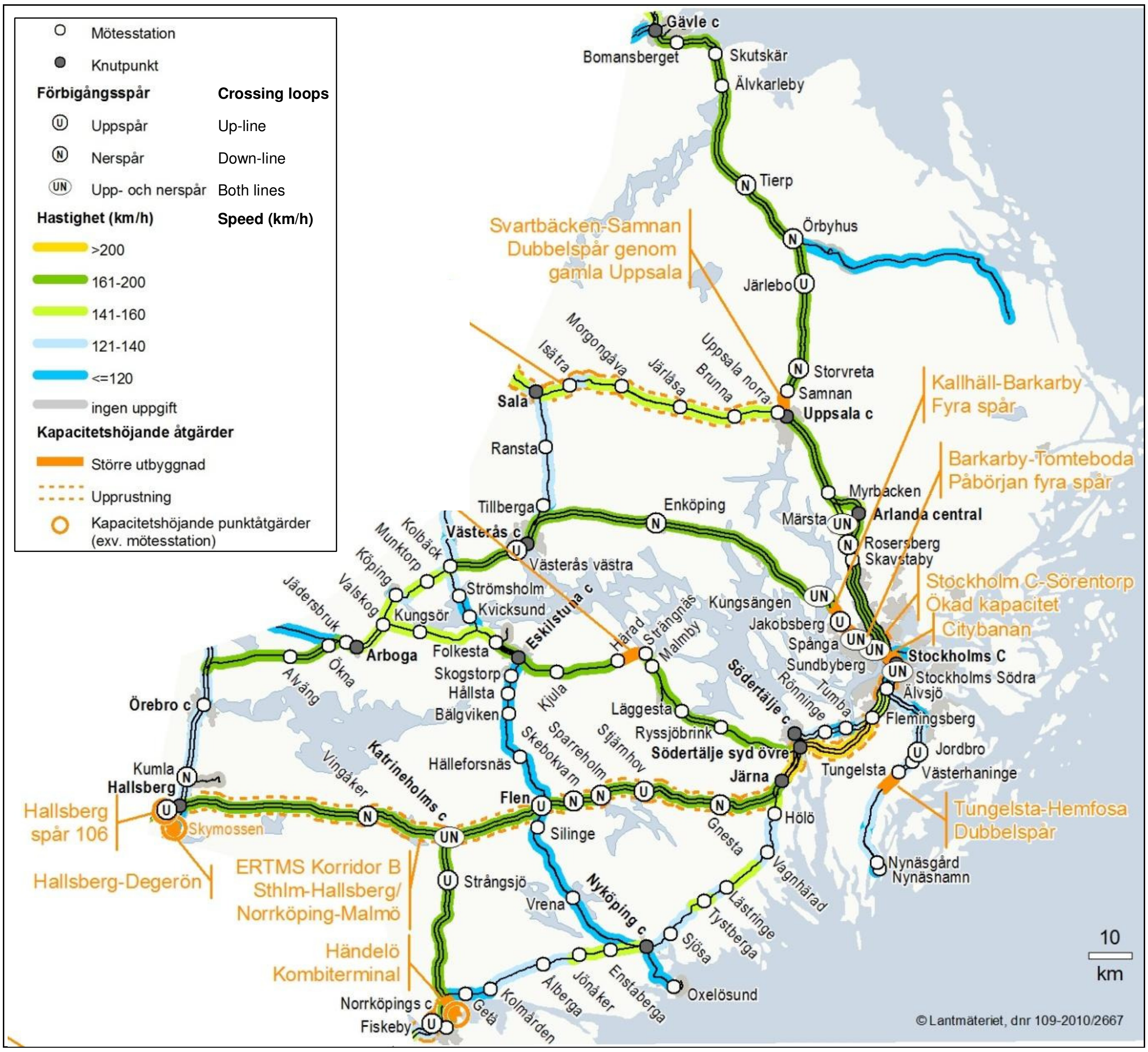
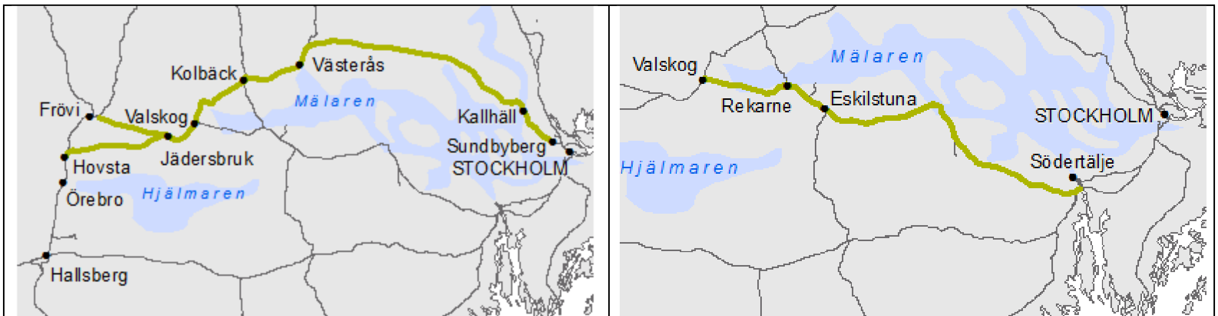


Figure 4.4: Mälardalen rail network map

Source: Trafikverket: http://www.trafikverket.se/Pressrum2/faktamaterial/Kapacitetsutredningen/



Mälarbanan (Mälaren line)	Svealandsbanan (Svealand line)
Double track between Stockholm and Kolbäck 200 km/h operation with no need for tilting trains Traffic a mix of regional/IC passenger and freight	Single track, double track Nykvarn-Läggesta Single track is limitation on capacity of line 200 km/h operation with no need for tilting trains

Figure 4.5: Mälaren and Svealand lines

Source: Trafikverket (2012); järnväg.net (2012): http://www.xn--jrnvg-grad.net/

4.2.2 Regional high-speed rail services

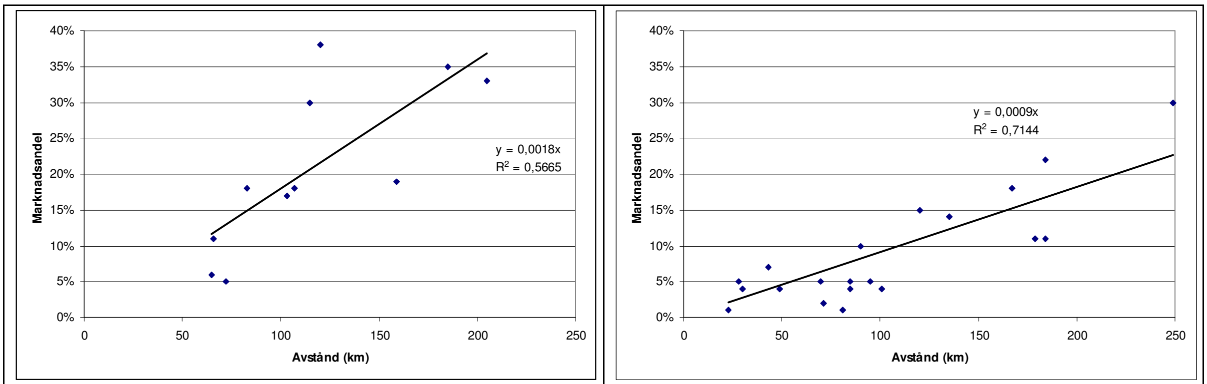
Regional high-speed services in the Stockholm-Mälaren region consist of fast regional and inter-city trains. Table 4.2 summarises the service data between Stockholm and the important Mälardalen regional cities for the main regional lines. Travel time is divided into shortest time (representing fast regional and inter-city services) and average time (considering all direct services: regional, fast regional, and inter-city); departures are averages of to/from Stockholm. A brief summary of the rail services on each line is given thereafter.

Table 4.2: Summary of service data between Stockholm and key Mälardalen cities

Rail line	Station	*Dist to Sthlm (km)[1,2]	Travel time (hrs)[1]		Departures[1]		Price[3] (kr)	+Rail Share[4]
			Short 2012	Avg 2012	Deps 2012	Freq 2012	2cl / low 2009	2002
Svealand	Nykvarn	50 (49)	0:28	0:30	15	1:11		
	Läggesta	67 (65)	0:38	0:40	15	1:11		
	Strängnäs	83 (89)	0:46	0:48	15	1:11		51 / 18
	Eskilstuna	115 (112)	0:53	1:06	15.5	1:09	130 / 74	54 / 30
	Kungsör	141 (135)	1:25	1:28	12	1:29		39 / -
Mälaren	Enköping	72 (80)	0:38	0:40	20	0:52		12 / 5
	Västerås	107 (110)	0:50	1:00	21	0:50	130 / 74	36 / 18
	Köping	141 (147)	1:11	1:17	14.5	1:11		26 / -
	Arboga	159 (151)	1:22	1:30	15.5	1:07		35 / 19
	Örebro/Hallsb	205 (196)	1:47	2:08	15.5	1:06	230 / 95	59 / 33
East Coast	Uppsala	69 (72)	0:37	0:39	44.5	0:24	71 / 45	32 / 11
	Tierp	131 (130)	1:03	1:30	34.5	0:37		
	Gävle	182 (175)	1:24	1:28	21	0:50	339 / 95	
Nyköping	Nyköping	103 (102)	1:01	1:03	14	1:14	130 / 74	44 / 17
Western Main Line	Flen	108 (117)	0:58	1:02	10	1:36		- / 38
	Katrineholm	131 (143)	0:54	0:58	22	0:43		- / 38
Southern Main Line	Norrköping	162 (162)	1:15	1:20	21	0:46		- / 35
	Linköping	209 (199)	1:39	1:52	21	0:46	303 / 95	- / 35

*Distance to Stockholm: Railway distance (Road distance)
+Rail Share: -Stockholm Central / -*Stockholm County*
Sources: [1]Resplus (2012); [2]www.freemaptools.com/, [3]Nelldal & Troche (2010); [4]Fröidh (18 sep 2003)

The most interesting aspect to Table 4.2 is the relationship between distance/travel time and rail market share; frequency is also important but in most cases it is fixed at around one hour. It shows that rail's share is considerable for journeys of around (and in excess of) one hour, corresponding to distances from about 100 km. It is markedly greater for trips to/from central Stockholm than to/from the entire county. This reflects a high service quality to/from central Stockholm in comparison to suburban areas and that there is a smaller market for shorter distances travelled between the suburbs and outlying municipalities (Fröidh, 18 sep 2003). It is important to note that the market share values are based on the forecast model 'SAMPERS' and thus contain inaccuracies and can only be considered a guide.



Rail share to/from Stockholm County	Rail share excluding to/from Stockholm

Figure 4.6: Rail market share in Mälardalen to/from Stockholm
Source: Fröidh (18 sep 2003) *Marknadsundersökning för tågtrafik i Mälardalen*

Figure 4.6 indicates the relationship between distance and rail's market share between cities in the Mälardalen. Considering trips to/from Stockholm County, rail's share starts to become significant (exceeding 20%) from around 100 km, the distance at which rail starts becoming competitive against road. Excluding trips to/from Stockholm, rail's share is markedly lower, reflecting less frequent and longer cross rail journeys against which road is more competitive.

The conclusion that can be drawn from the above data is that fast regional services are most competitive against road from distances of around 100 km (corresponding to travel times of around one hour) with regular (hourly) departures and affordable pricing. Shorter commuting distances do however have the potential to capture a significant market share with fast higher frequency services, as in the case of Uppsala; this depends also on competition from car, as congestion and expensive parking raise the share of public transport.

Table 4.3 below details the timeframe of line upgrades and the introduction of regional high-speed services on the different Mälardalen lines, all of which were progressively introduced in the mid-late 1990s with the exception of Stockholm-Nyköping. The service characteristics, ticket prices and rail market shares indicated in Table 4.2 are thus representative of regional high-speed services in operation. The train types are described briefly in the next section.

Table 4.3: Introduction of high-speed services in Mälardalen
Source: järnväg.net (2012): http://www.jarnvag.net/index.php/banguide

Rail line	High-speed services introduced	Max speed	Trains
Svealand line	Rebuilt line opened in June 1997	200 km/h	X40
Mälaren line	Progressive upgrades in 1993, 1995, new services 1997, completed in 2001	200	X40
East Coast Line	Upgrades in early 1990s	200	X40 / loco
Nyköping line	Not yet upgraded	140-160	loco/EMU/X40
Western Main Line	Upgrades in early 1990s	200	X40 / X2
Southern Main Line	High speed trains introduced in 1995	200	X40 / X2

4.2.3 Regional high-speed lines and trains

A brief description of regional high-speed lines in the Stockholm-Mälaren region and trains servicing those lines is given hereunder. (Source: järnväg.net, 2012)

Svealand line (Svealandsbanan) – Stockholm-Eskilstuna*-Arboga*

Services consist of regular direct regional trains between Stockholm Central and Eskilstuna that stop at all intermediate stations; continuing on to Arboga requires a change at Eskilstuna, from which there are fewer departures (12). Trains are SJ X40 type.

Mälaren line (Mälarbanan) – Stockholm-Västerås-Örebro*-Hallsberg*

Services consist of regular direct regional trains between Stockholm Central and Västerås, with most trains continuing to Örebro. All but one Stockholm-Västerås and two Stockholm-Örebro peak hour fast trains stop at all intermediate stations. Trains are SJ X40 type.

East Coast Line (Ostkustbanan) – Stockholm-Uppsala-Gävle

Services on this heavily trafficked line include regional commuter trains between Stockholm and Uppsala, regional trains between Upplands Väsby (in Stockholm County with commuter train connection to central Stockholm)-Tierp-Uppsala-Gävle and fast-IC-regional trains between Stockholm-Arlanda airport-Uppsala-Gävle. Trains are SJ X40 type from Stockholm to Gävle, Regina type between Upplands Väsby-Gävle and older locomotive hauled trains for the commuter service between Stockholm and Uppsala.

Nyköping line (Nyköpingsbanan) – Stockholm-Nyköping*-Norrköping*

Services on this line are slower regional trains between Stockholm and Nyköping, continuing on to the larger cities of Norrköping and Linköping; trains stop at all intermediate stations and are generally locomotive-hauled trains and occasionally some older EMU and X40. With an average speed of around 100 km/h, the service is considerably slower than ‘fast’ regional services on other lines.

Västra- & Sodra stambanan (Western- and Southern Main Line)

Services on these lines consist of high-speed inter-city, fast and regional trains. Trains from Stockholm to Norrköping-Linköping (not via Nyköping) are non-stop (SJ X40 type trains) and those to Katrineholm are regional trains stopping at intermediate stations, or non-stop high-speed (SJ X2) inter-city trains.

Sala-Västerås-Norrköping cross line

Services on this interconnecting cross line consist of hourly regional trains travelling between Västerås and Norrkoping via Eskilstuna, Flen and Katrineholm using various electric multiple unit trains (SJ X12, X50 and sometimes X40). The section of line Flen-Nyköping-Oxelösund no longer carries passenger traffic, only freight.

The trains referred to above are illustrated with their key characteristics in Figure 4.7.

Train types

		
SJ X40 double-decker EMU[1] Capacity: 153 (2 car)/ 252 (3 car) Maximum speed: 200 km/h	SJ X2 high-speed tilting train[1] Form: 1 loco & 5 or 6 coaches Maximum speed: 200 km/h	SJ X12 older type EMU[2] Formation: 2 cars Maximum speed: 160 km/h
Sources: [1]Wikipedia (2008); [2]http://flickrhivemind.net/Tags/sjab/Interesting		

Figure 4.7: Train types serving the Mälardalen regional lines

The SJ X40 trains were gradually put into service from 2005, replacing X2, locomotive-hauled and fast regional 'Regina' trains.

4.3 Effects of high-speed rail on travel patterns

There are few studies concerning the introduction of regional high speed trains in the Mälaren valley, particularly regarding rail traffic development and the change in rail's market share. The Svealand line ('Svealandsbanan' in Swedish) is the most studied regional high-speed line in the Mälaren valley. Fröidh (2003), in his thesis titled "Introduction of regional high speed trains: a study of the effects of the Svealand line on the travel market, travel behaviour and accessibility", presents the short term transport effects of the introduction of high-speed trains and touches on the emergence of longer-term regional effects. It is the most comprehensive before-and-after study of a Mälaren valley regional high-speed line and, in the absence of similar studies of other lines, serves as an example of what can be achieved on regional lines with similar supply improvements and geographic/demographic characteristics.

This section will summarise the short-term trends of improved rail supply in the Stockholm-Mälaren region and the key findings of Fröidh's (2003) Svealand line study. The subsequent section will then attempt to relate them to changes in commuting patterns for a selection of municipalities in the Mälaren valley, the purpose being to establish a link between the supply improvements and growth in rail travel and commuting, which itself has longer-term regional implications.

4.3.1 General trends over region

There is limited available information on passenger trips and growth given the competitive environment for rail in the Stockholm-Mälaren region. Figure 4.8 illustrates the daily average passenger load on some key regional high-speed lines.

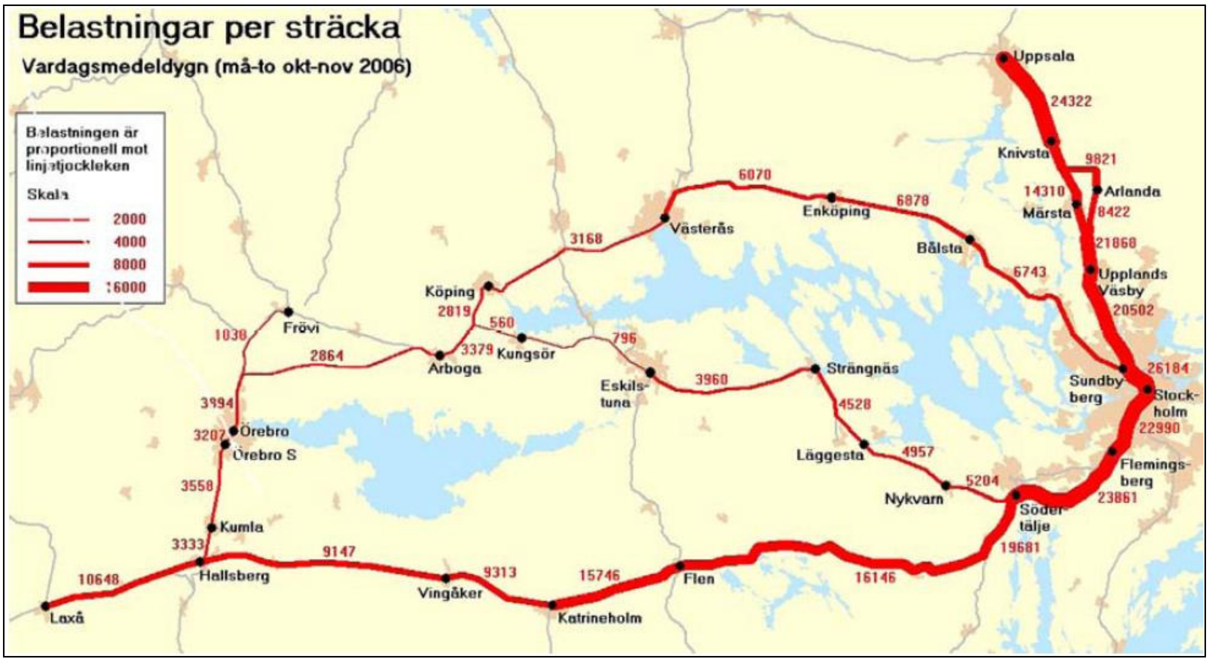
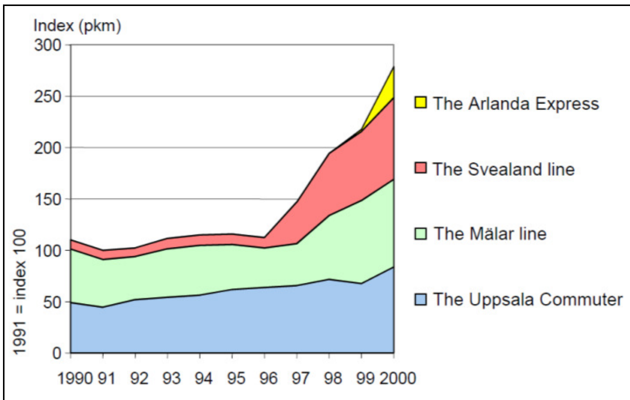


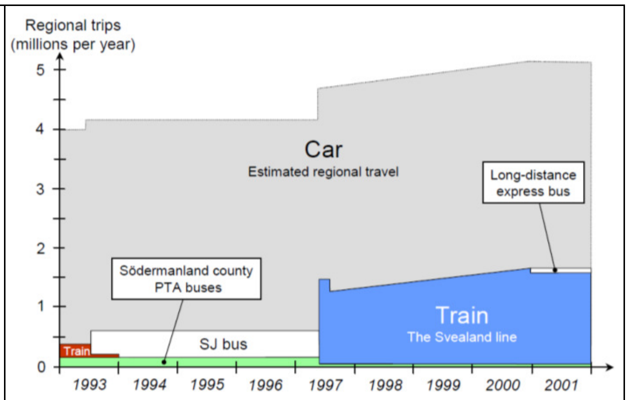
Figure 4.8: Passenger load per distance, daily average Monday-Thursday, 2006
Source: Banverket (2007)

Regional journeys make up the vast majority of trips, except for services via Katrineholm and Hallsberg which include the sizeable high-speed inter-city market. The Mälaren and Svealand lines carry similar a scale of traffic while Stockholm-Uppsala carries a much higher quantity, including trips to/from Stockholm's Arlanda airport.

Figure 4.9 charts regional passenger growth between 1990 and 2000 on some Mälaren valley lines (left) and indicates the share of regional travel on the Svealand corridor over the county border (right). The Svealand line reports the highest growth, followed by the Mälaren line.



Regional travel on some Mälaren valley lines, 1990-2000 (Source: Nelldal and Troche, 2001)



Share of regional travel over the county border, 1993-2001 (Source: Fröidh, 2003)

Figure 4.9: Regional rail travel in the Mälaren valley

4.3.2 Svealand line: short-term effects on travel market and travel behaviour

The Svealand line was opened in 1997 and consists of a newly built, mostly single track, line from Södertälje to Eskilstuna (79 km), and a modernised section from Eskilstuna to Valskog (35 km), allowing trains to continue to Örebro and Hallsberg. The new line permits regional high-speed trains running at a maximum speed of 200 km/h to traverse Stockholm-Eskilstuna (115 km) in around one hour with five intermediate stops. The main aims were to facilitate daily commuting and to spread the economic growth from Greater Stockholm to surrounding areas through improved accessibility (Fröidh, 2003).

The overall finding from the Svealand line study is a seven-fold increase in travel demand and the capture of around 30% of the regional transport market following the introduction of high-speed trains. While this remarkable achievement speaks for itself, some aspects deserve additional comment.

The improved supply between Stockholm and Eskilstuna generated significant increases in travel in the years following its introduction, as summarised in Table 4.4. The most dramatic increase came with the introduction of the high-speed trains, which in supply terms amounted to a 40% reduction in journey time and a doubling of services in comparison to previous train services. A subsequent increase in fare price in the same year caused a slight drop in demand but this was offset by continued growth in subsequent years. It is worth noting that the figures in Table 4.4 don't include intra-regional trips (not crossing county borders) and inter-regional trips between Örebro and Stockholm that previously went via Hallsberg (Fröidh, 2003). Of the new rail passengers, around half were former bus passengers and the other half were new passengers, of which a modest proportion (15%) had transferred from car.

Table 4.4: Supply and demand: regional travel on SJ between Eskilstuna and Stockholm
Source: Fröidh (2003)

Period	No. services Mon-Fri each direction	Travelling time (hrs:mins)	Fare, single, 2nd class (SEK)[1]	No. journeys (000's/yr)[2]	Incr. factor
Up to spring 1993	8 trains	1:40	115	230	1
Autumn 1993 - spring 1997	18 buses	1:55-2:20	105-120	440	2
Summer 1997	17 HS trains	1:00	55	1400	6
Autumn 1997	17 HS trains	1:00	110	1200	5
2001	18 HS trains	1:02	113-135	1600	7

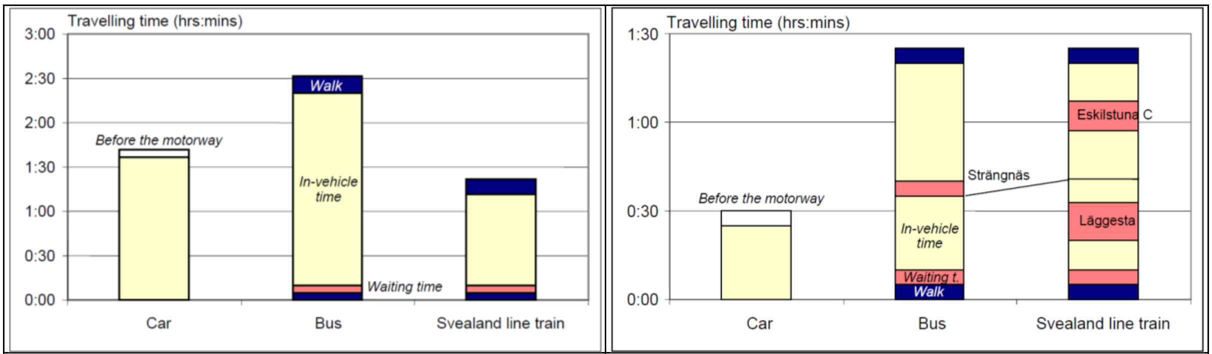
[1] Fares are shown in 2003 prices
[2] Regional travel over the county border (Läggesta–Nykvarn section)

Market share for rail increased from 6% to about 30% for regional trips (between Eskilstuna and Stockholm or shorter) in the E20 / Svealand line corridor. Rail's share for journeys across different points in the Svealand corridor is summarised in Table 4.5. For travel that requires a connection to reach destinations bordering the corridor, the market share for rail is lower.

Table 4.5 Market shares for regional travel on Svealand line
Source: Fröidh (2003)

Market shares for regional travel	Point east of Strängnäs			Over the county border			Eskilstuna/Strängnäs - Södertälje/Stockholm		
Journeys per year, mil	1993	1996	2000	1993	1996	2000	1993	1996	2000
Total regional travel	3.7	3.9	4.7-5.0	4.0	4.2	5.0-5.4	2.8	3.0	3.7-4.2
Car	87%	82%	68-70%	90%	86%	68-70%	91%	85%	62-67%
Public transport	13%	18%	30-32%	10%	14%	30-32%	9%	15%	33-38%
of which LT buses	8%	7%	2%	4%	4%	1%	2%	2%	
SJ trains	5%			6%			7%		
SJ buses		11%			10%			13%	
SJ high speed trains			28-30%			29-31%			33-38%

The variation in market share for rail between longer-distance direct connections and shorter-distance multiple change connections is explained by Figure 4.10. For journeys where train is faster than car (Eskilstuna-Stockholm), rail is able to capture a significant market share; while where it is considerably slower (Åkers styckebruk–Eskilstuna), the share is much lower.

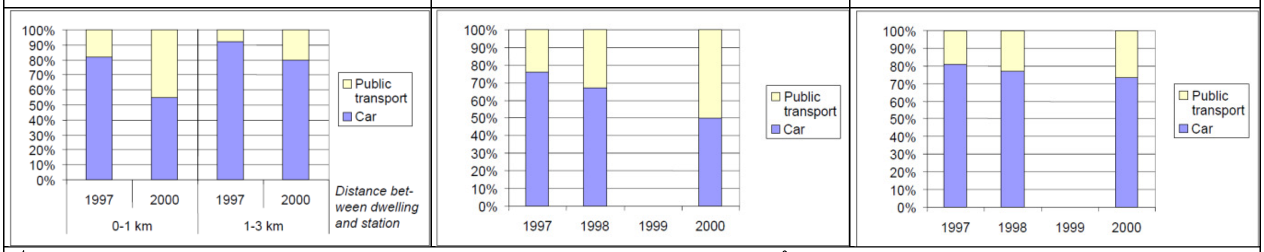


Centre of Eskilstuna–Centre of Stockholm | Åkers styckebruk–Eskilstuna

Figure 4.10: Journey times compared by different modes (Source: Fröidh, 2003)

Distribution by travel mode for journeys along the E20 / the Svealand line, 1997-2000

Living in Strängnäs | Walking distance from the station in Eskilstuna | Svea conurbations AB+D'[1]



[1] Svea conurbations AB+D' are residents of Nykvarn, Mariefred, Åkers styckebruk, Strängnäs and the centre of Eskilstuna, weighted (Source: Fröidh, 2003)

Figure 4.11: Distribution by travel mode: journeys along E20 / Svealand line

Improved accessibility as a result of the Svealand line affected distribution of transport mode, as observed in journeys along the E20 / Svealand line (refer Figure 4.11 above). While there is a visible increase in the share for public transport over time in all cases, the effects are greatest for residence living near to a train station.

Reduced travel times have increased the accessibility of the regional centres to larger labour markets, most notably that of Stockholm, as depicted in Figure 4.12 for Eskilstuna. The left chart plots the effect on the number of jobs that can be accessed from the centre of Eskilstuna with a half-hour reduction in journey time that is assumed to represent gains from high-speed rail. The right chart indicates the increased accessibility to jobs enabled by train over bus that starts to become significant after 60 minutes journey time.

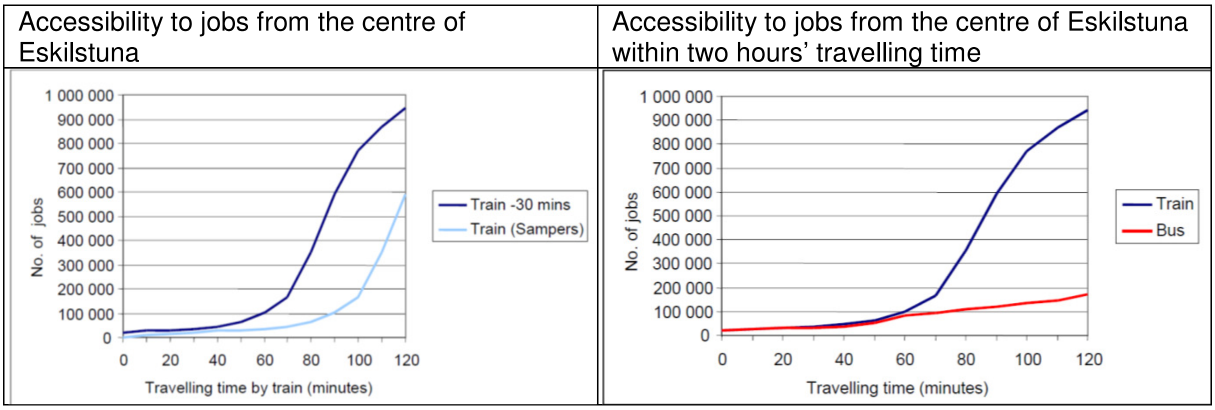


Figure 4.12: Accessibility to jobs from Eskilstuna
Source: Fröidh (2003)

Increased accessibility to larger labour markets is reflected in the extent of commuting. Total commuting to and from the municipalities increased between 1996 and 2000, as presented in Table 4.6. The growth in both outward and inward commuting reflects increased accessibility to labour markets throughout the region and increased attractiveness of the municipalities. Nyköping, which did not experience an improved supply, is presented as a reference case.

Table 4.6: Total commuting in the municipalities in 1996 and 2000
Source: Fröidh (2003)

No. of commuters	Outward			Inward		
	1996	2000	Change	1996	2000	Change
Eskilstuna	3665	5109	+39%	3661	4420	+21%
Strängnäs	4317	5100	+18%	1426	2792	+96%
Nyköping	4437	5012	+13%	2845	3122	+10%

The change in proportion of inward and outward commuting from and to the municipality of Stockholm reflects the relative improvement in accessibility to Stockholm's labour market in relation to the other municipalities. The share of out-commuting to Stockholm rose sharply for Eskilstuna and Strängnäs, while the share of in-commuting from Stockholm remained relatively stable in both cases, as depicted in Figure 4.13.

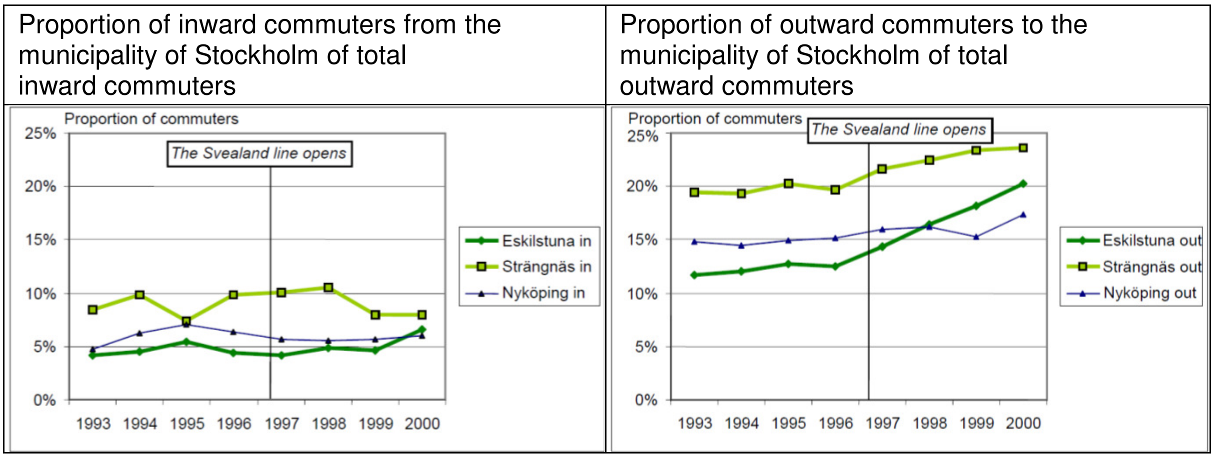


Figure 4.13: Proportion of commuters to/from the municipality of Stockholm of total
Source: Fröidh (2003) / SCB

As Stockholm is the largest labour market in the region, it is no surprise that out-commuting (to Stockholm) exceeds in-commuting (to the regional centre). Figure 4.14 below depicts the level of commuting to and from Stockholm from different municipalities. The municipalities of Eskilstuna and Strängnäs, which are served by the Svealand line, indicate strong growth in out-commuting in the years following the opening of the new line; there is a delayed gradual increase in in-commuting to Eskilstuna, which is explained by the relocation of several businesses from Stockholm to Eskilstuna and the expansion of Mälardalen University (Fröidh, 2003).

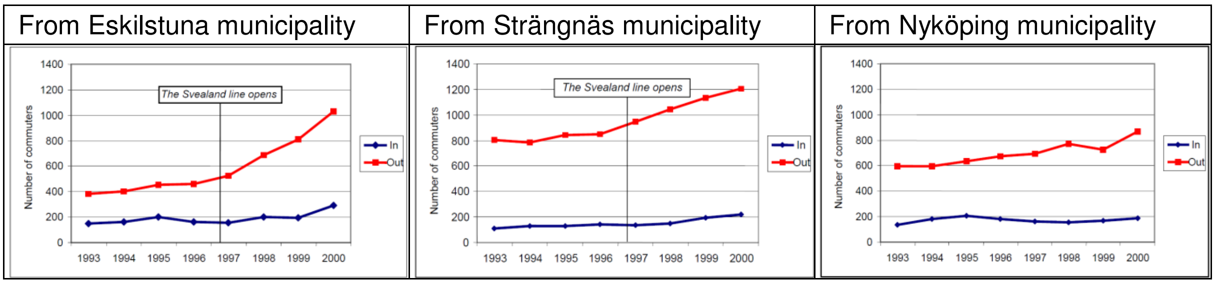
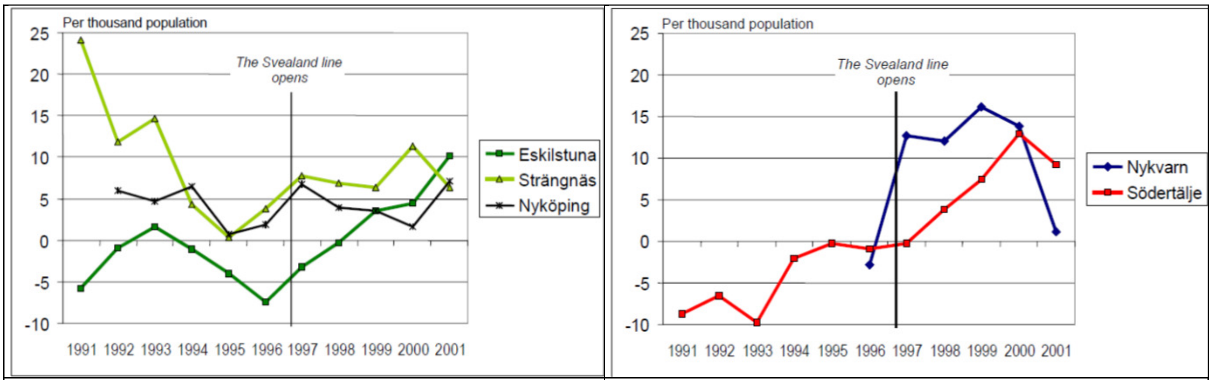


Figure 4.14: Commuting to and from Eskilstuna municipality to/from Stockholm municipality, 1993-2000. Source: Fröidh (2003) / SCB

Changes in population and employment represent longer-term regional effects. Although the post-introduction study period (1997-2001) is quite short when considering regional effects, it signals the emergence of more permanent effects, such as the movement of economic activity and population resettlement.

Changes in net migration in different municipalities affected by the Svealand line are plotted in Figure 4.15.

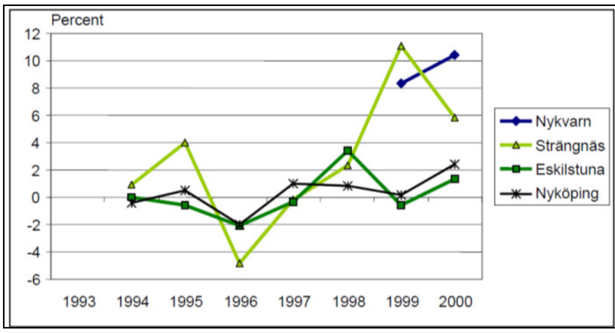


Eskilstuna, Strängnäs and Nyköping municipalities (Södermanland County)	Södertälje and Nykvarn municipalities (Stockholm County)

Figure 4.15: Net migration in municipalities, 1991-2001
Source: Fröidh (2003) / SCB

Population growth was consistently positive in the Södermanland municipalities following the opening of the Svealand line, although Eskilstuna didn't achieve positive growth until 1998 but experienced rapidly increasing growth thereafter. The Stockholm municipalities, in comparison, experienced a rapid increase in population growth in the first three years after the line's opening, followed by a decline but retaining an overall positive growth. A positive net migration in all municipalities depends largely on people moving in (Fröidh, 2003).

Changes in the number of jobs and the job to population ratio for the municipalities are given in Figure 4.16. Change in the number of jobs was generally positive in all municipalities from 1997: significant in Strängnäs and Nykvarn, lower in Eskilstuna. The job to population ratio, also known as the degree of self-sufficiency, is the ratio between the number of jobs and the number of gainfully employed people in a municipality (Fröidh, 2003). It increased steadily in Strängnäs and Nykvarn (signalling growth in local labour markets and increasing degree of self-sufficiency) and decreased slightly in Eskilstuna (signalling a growing out-commuting).



Municipality	Job to population ratio 1990	1998	2000
Eskilstuna	101%	100%	98%
Strängnäs	78%	75%	83%
Nykvarn	32%	36%	41%
Nyköping	-	91%	91%

Source: Fröidh (2003) / SCB

Figure 4.16: Change in number of jobs, 1994-2000; Job to employment ratio
Source: Fröidh (2003) / SCB

The results presented thus far on the Svealand line are sourced from Fröidh's 2003 study and are limited to the study period early-1990s to 2001, or until four years after the opening of the new line. The report 'Svealandsbanan första 10 år - erfarenheter för framtiden av tågtrafiken och resandet' (Fröidh and Lindfeldt, 2008) presents a brief update on the line's progress and some updated trip quantities. Table 4.7 includes travel for the time series 1997-2007 based on SJ ticket statistics, which are approximately 20% lower than passenger counts indicate.

Table 4.7: Travel on the Svealand line based on SJ ticket statistics.
Source: Fröidh and Lindfeldt (2008) / SJ

Full year	Trips on Svealand line	Change from previous year
1997	1 207 100	
1998	1 224 417	1.4%
1999	1 488 231	21.5%
2000	1 869 400	25.6%
2001	1 802 903	-3.6%
2002	1 531 224	-15.1%
2003	1 458 543	-4.7%
2004	1 457 537	-0.1%
2005	1 504 803	3.2%
2006	1 616 721	7.4%
2007	1 719 818	6.4%

The figures reveal a decrease in travel after reaching a peak in 2000, dropping to a low point in 2004, then slowly recovering with steady growth up to 2007. The decrease in travel from 2002 coincides with increasing delays (considered to be the most significant factor), falling petrol prices, change to trains with lower customer value and declining economic activity.

4.4 Emergence of longer-term regional effects

This section analyses the longer-term changes in commuting patterns, population and jobs for a selection of municipalities in the Stockholm-Mälaren region. It attempts to establish a link between the supply improvements and growth in commuting, and seeks signs of emerging population and job growth in the longer term.

4.4.1 Basis for assessment of regional effects

The extent of commuting is a useful measure for assessing short-term and medium-long term effects of an improved transport supply. In the short term, an increased accessibility to labour markets is reflected in increased commuting as more people are able to make longer journeys to work. In the longer term, growth in outward commuting may signal increased in-migration as new residents are attracted to and move into the region and commute to their current jobs; growth in inward commuting may signal an increase in local economic activity as businesses relocate from the large city (Stockholm) to the region and workers commute in from outside, although this could be offset by the growth of local labour markets. Commuting behaviour cannot entirely explain population changes and economic development (long-term population and economic indicators are also needed to establish a stronger pattern of change) but, as demonstrated in the Svealand line study, it can signal emerging long-term effects that may be supported by observed changes in population and number of local jobs. Change in population reflects the attractiveness of a region for new settlement while the number of jobs and job to population ratio (degree of self-sufficiency) reflects the region's economic strength and the tendency to attract workers from outside to fill surplus jobs.

This analysis studies commuting patterns (total or to/from Stockholm depending on distance from the capital) over a wide area of the Stockholm-Mälaren region to establish the influence of high-speed rail and looks at changes in population and jobs to confirm its longer-term effects. The data (sourced from SCB, 2012) does not distinguish between different modes and hence changes in commuting cannot be attributed solely to improved rail supply. Nonetheless, sudden changes coinciding with the introduction of high-speed rail services are a telling sign of its likely impact.

4.4.2 Regional effects by city groups

To examine changes in commuting patterns in the Stockholm-Mälaren region where regional high-speed trains have been introduced, this study considers three groups of cities of similar distance from Stockholm, population size and character for which commuting data in recent years has been analysed; one city in each group is taken a reference city that has experienced no significant rail supply improvements in the time period considered while the other cities have seen the introduction of high-speed services. Three groups of cities are considered: large regional around 90 km from Stockholm; small-medium around 120 km, and small-medium around 60 km. The characteristics of the cities are summarised in Table 4.8.

Table 4.8: City characteristics, city groups

Sources: [1]Resplus (2012); [2]www.freemaptools.com/; [3]SCB (2012)

Line	City	Dist to Sthlm	Population[3]		Travel time (hrs:mins)[1]	
		Rail (Road)[1,2]	City	Municipal	Short	Average
Svealand	Eskilstuna	115 (112)	64,679	96,311	0:53	1:06
Mälaren	Västerås	107 (110)	110,877	137,207	0:50	1:00
	Nyköping	103 (102)	29,891	51,644	1:01	1:03
Mälaren	Köping	141 (147)	17,743	24,905	1:11	1:17
Mälar/Svea	Arboga	159 (151)	10,330	13,285	1:22	1:30
	Sala	131 (120)	12,289	21,535	1:20	1:20
Svealand	Strängnäs	83 (89)	12,856	32,419	0:46	0:48
Mälaren	Enköping	72 (80)	21,121	39,759	0:38	0:40
	Trosa-Vagn	68 (71)	8,697	11,462	0:38	0:42

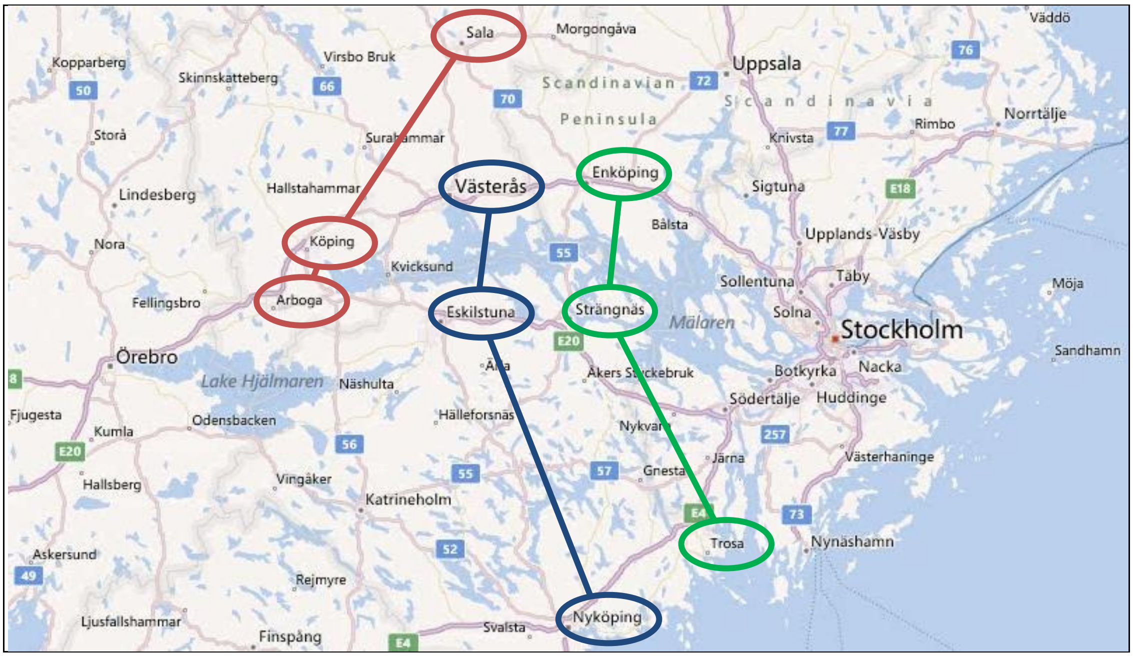


Figure 4.17: City groups depicted on map (Map source: Bing Maps, 2012)

Nyköping group (Eskilstuna, Västerås, Nyköping)

The Nyköping group includes the large regional centres of Eskilstuna (Svealand line) and Västerås (Mälaren line), each around 110 km and within one hour travel time of Stockholm. The Svealand line opened in 1997 and the Mälaren line received progressive upgrades over the period 1997-2003 to be considered a proper high-speed service by 2004. The proportion of commuting to/from Stockholm of total commuting is a useful indicator of the sustained effect of increased accessibility between Stockholm and regional centres within a reasonable commuting range. A time series of the proportion of inward (from Stockholm) and outward (to Stockholm) commuting between 1995 and 2010 is given in Figure 4.18. Nyköping, which has not experienced supply improvements but is accessible from Stockholm in one hour, is the reference case.

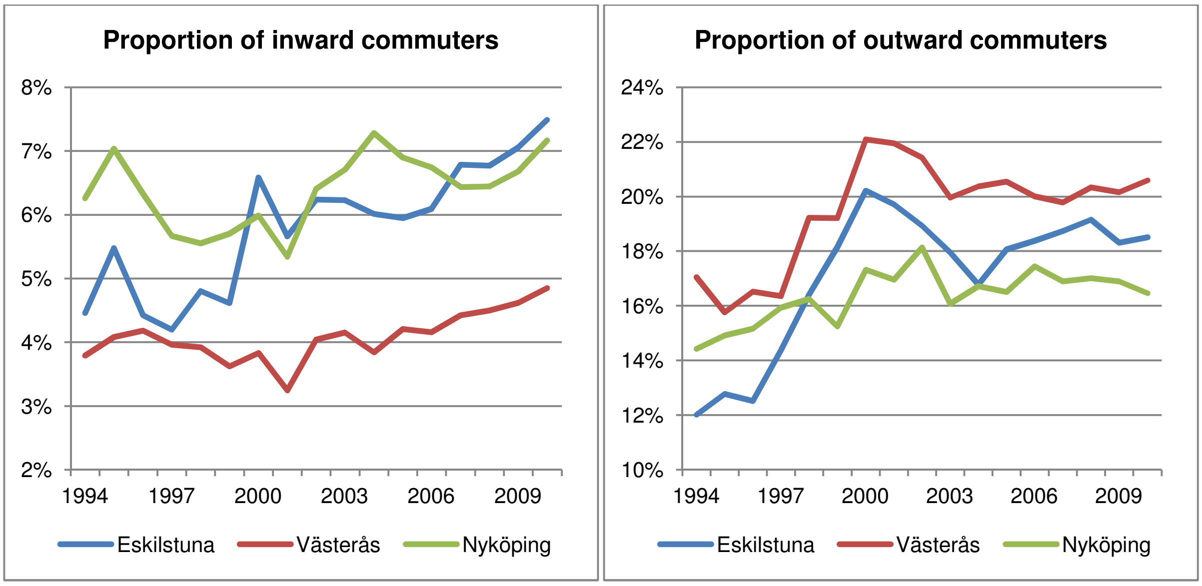


Figure 4.18: Proportion commuting to/from Stockholm: Eskilstuna, Västerås, Nyköping

The proportion of inward commuting from Stockholm rapidly rises for Eskilstuna a few years after the introduction of high-speed, signalling the emergence of attractive work possibilities for Stockholm residents willing to commute for new jobs. A similar effect starts to emerge in Västerås after the last upgrades to high-speed in 2003. The proportion of outward commuting to Stockholm rapidly increases for both cities following upgrades, reflecting the immediately improved accessibility to Stockholm's large labour market. Nyköping experienced marginal increases in inward and outward commuting, unmarked in the absence of line improvements.

Absolute volumes of inward and outward commuting to and from Stockholm for each city area are given in Figure 4.19.

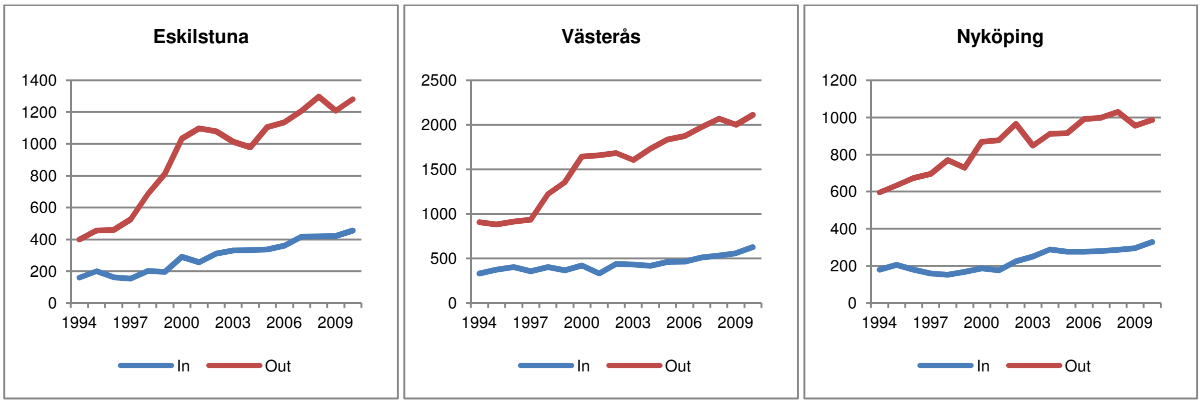


Figure 4.19: Commuting volumes to/from Stockholm: Eskilstuna, Västerås, Nyköping

Rapid growth in outward commuting to Stockholm is observed for Eskilstuna and Västerås in the period following the introduction of high-speed services in 1997; in each case, growth slows from 2000-2001 for around 3 years before resuming upward. Inward commuting is initially steady but after a sustained period of high-speed services it begins to rise slowly. The gradual rise in inward commuting may indicate increased local economic activity and job growth. Nyköping experienced steady positive growth in commuting over the same period but the absence of a sudden boost in outward commuting from 1997, as seen in the other cities, is evidence of the effect of rail supply improvements on commuting to/from Stockholm.

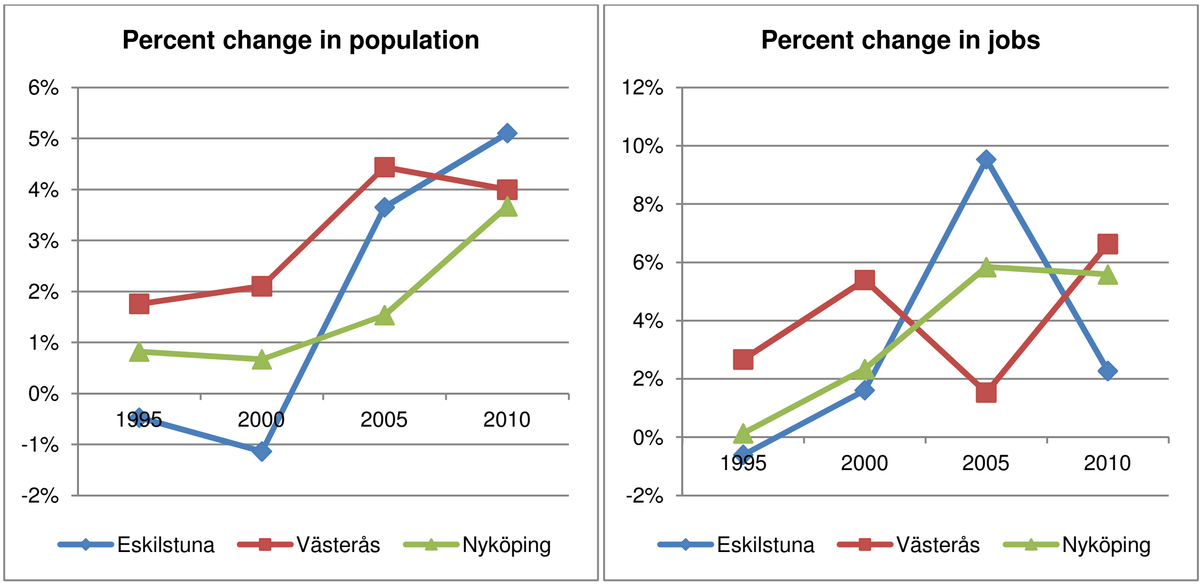


Figure 4.20: Change in population and jobs: Eskilstuna, Västerås, Nyköping

Population change in each case can be linked to the improvement of rail services. In Västerås, major improvements to rail services in 1998 and 2000 are matched by increases in population growth, which stabilises at around 4% (with further improvements 2002-2003). In Eskilstuna, after a period of negative growth, positive growth starts to emerge a few years following the opening of the line in 1997 and continues to rise to a peak of around 5%. The rapid increase in population growth in Eskilstuna and Västerås can reasonably be attributed to the advent of high-speed rail while a more gradual increase in Nyköping can be explained by "background" growth experienced by all significant centres of similar proximity to Stockholm.

Job growth increased rapidly in the years following rail improvements but plateaued and even decreased in the case of Eskilstuna from 2005, possibly due to external economic factors. The overall strong positive growth is a clear indicator of the probable positive effect of improved rail services on the local economies.

Sala group (Arboga, Köping, Sala)

The Sala group includes the small-medium cities of Köping (Mälaren line), Arboga (Mälaren and Svealand line) and Sala as a reference city, each around 150 km from Stockholm. Sala is slightly closer to Stockholm (120 km) but its indirectness by rail travel via Uppsala compared to the more direct centres of Köping and Arboga renders it comparable in distance. The travel time between Stockholm and the three cities is around 1:15-1:25, which exceeds the generally acceptable daily commuting time of one hour; thus commuting between Stockholm and these cities is, as expected, very low with proportions of total commuting 0.5-2% (inward) and 2-6% (outward). A more relevant indicator that reflects commuting to/from other centres in the region is the total level of commuting, depicted for each city in Figure 4.21.

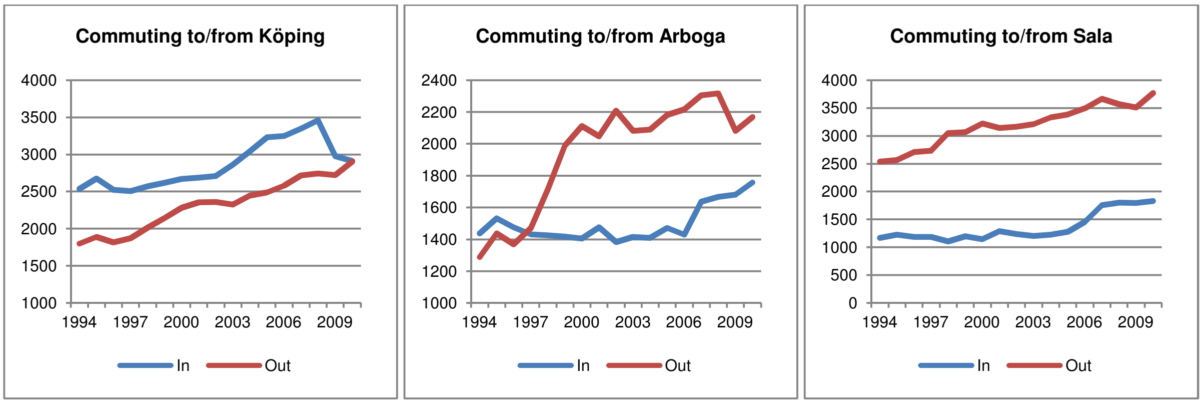


Figure 4.21: Total commuting volumes: Köping, Arboga, Sala

Köping experienced steadily increasing inward and outward commuting during and following upgrades to the Mälaren line (1997-2003); there was a particularly strong rise in inward commuting from 2002 and a tapering off from 2008, presumably due to economic factors. In comparison, Arboga experienced rapidly increasing outward commuting upon opening of the Svealand line and amidst upgrades to the Mälaren line; the sharp increase reflects coincident upgrades to both lines it is served by and thus increased accessibility to neighbouring regions. Sala, a reference city that has experienced no significant supply improvements over the same time frame, achieved a steady increasing volume of outward commuting with no major rises that would coincide with enhancements, as seen in Arboga and (to a lesser extent) Köping. Inward commuting was constant prior to a sudden rise from 2006, which was coincidently also experienced in Arboga.

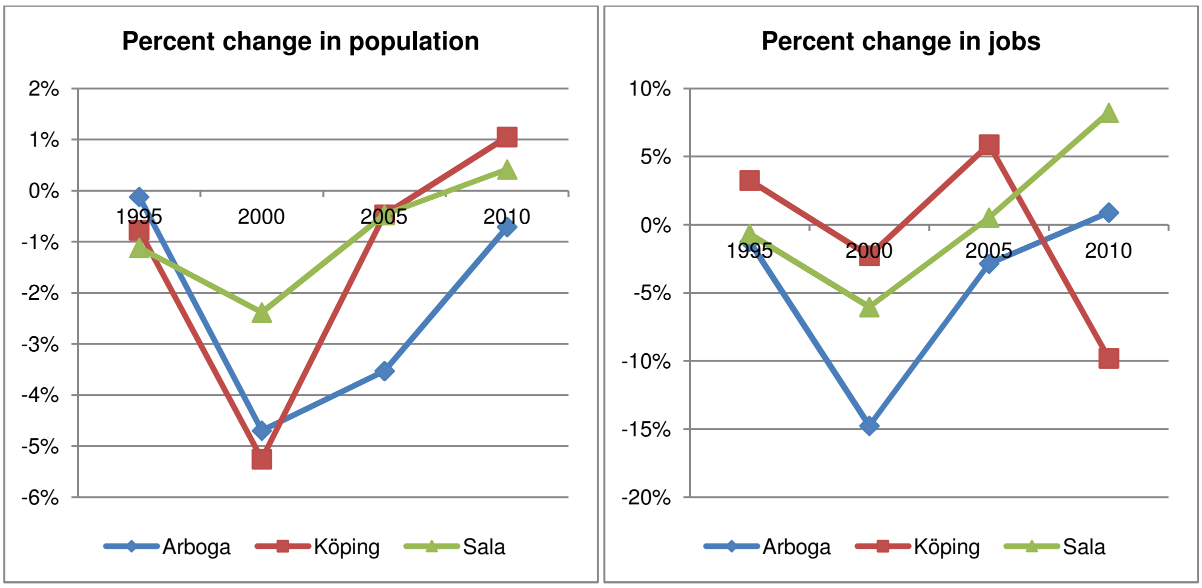


Figure 4.22: Change in population and jobs per 5 years: Köping, Arboga, Sala

Population and job growth was varied for Arboga and Köping and more stable for reference city Sala. Arboga experienced rapid decline in population and jobs between 1995 and 2000 (evidently as a result of Volvo's departure from the city in 1997) but achieved positive job growth and almost neutral population change by 2010. Köping experienced a similar decline in population but recovered to neutral by 2005, whence positive growth occurred; job growth fluctuated, rising from 2002 but declining after 2005 due to unknown factors. Despite their prolonged period of decline, their recoveries followed upgrades to rail services between 1997 and 2003, a signal of its positive effects on regional growth.

Trosa group (Strängnäs, Enköping, Trosa)

The Trosa group includes the small-medium cities of Strängnäs (Svealand line), Enköping (Mälaren line) and Trosa-Vagnhärad (Nyköping line) as a reference city, situated 70-90 km from Stockholm and accessible in around 40-50 minutes, a comfortable commuting time. A time series of changing proportion of inward (from Stockholm) and outward (to Stockholm) commuting between 1995 and 2010 is given in Figure 4.23. Trosa, which has not experienced supply improvements but is accessible from Stockholm in one hour, is the reference case.

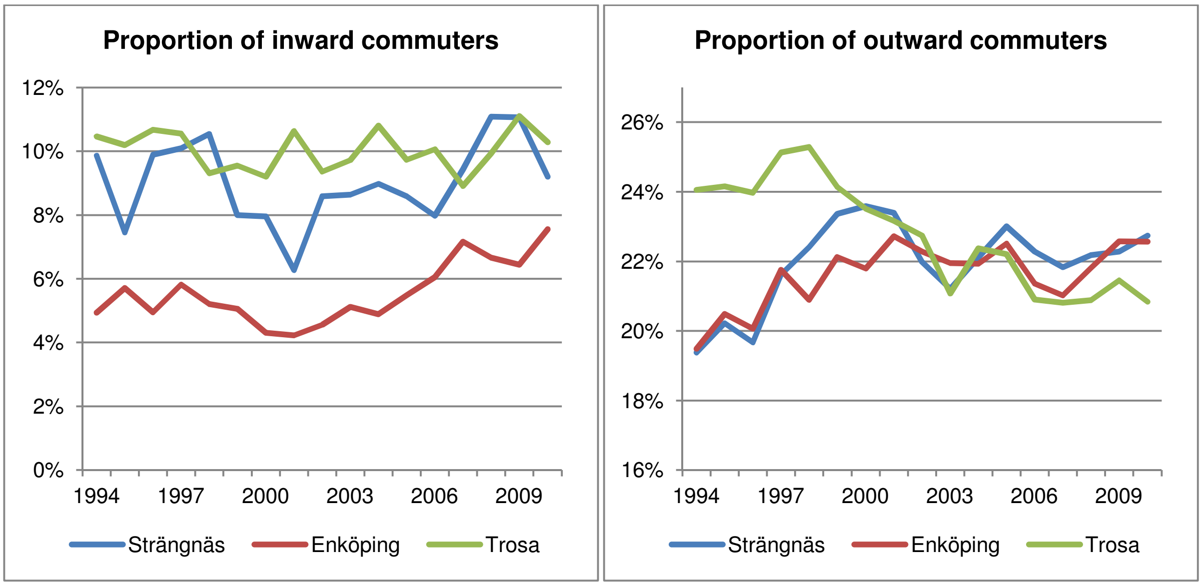


Figure 4.23: Proportion commuting to/from Stockholm: Strängnäs, Enköping, Trosa

The proportion of inward commuting from Stockholm is seen to steadily rise some years after line upgrades (from 2002-2003), a delayed effect which reflects possible dynamic changes to labour markets and improved opportunities in the regional cities for Stockholmers to work compared to other nearby regions. The proportion of outward commuting to Stockholm rises rapidly upon improvements to services and stabilises by 2003-2004. For the reference city of Trosa, inward commuting is static at around 10% and outward commuting decreases steadily against the trend for the high-speed connected cities.

Absolute volumes of inward and outward commuting to and from Stockholm for each city area are given in Figure 4.24.

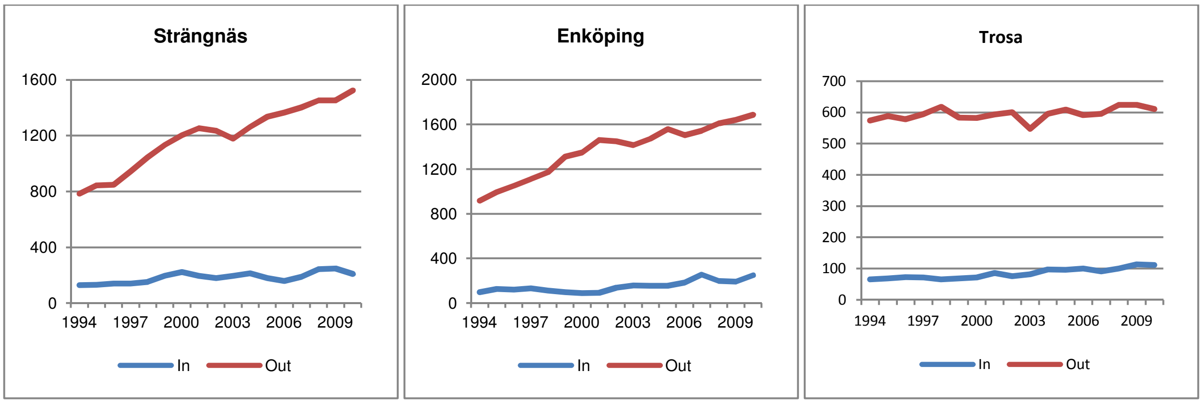


Figure 4.24: Commuting volumes to/from Stockholm: Strängnäs, Enköping, Trosa

Rapid growth in outward commuting to Stockholm is seen in Strängnäs and Enköping in the period following the introduction of high-speed services. Inward commuting from Stockholm is relatively flat, although there is a gradual increase in Strängnäs from the introduction year of 1997 and in Enköping from 2001 amidst its line upgrades towards true high-speed. Trosa experienced no change in outward commuting to Stockholm and a small gradual increase in inward commuting, evidence of the positive effects of supply improvements on commuting.

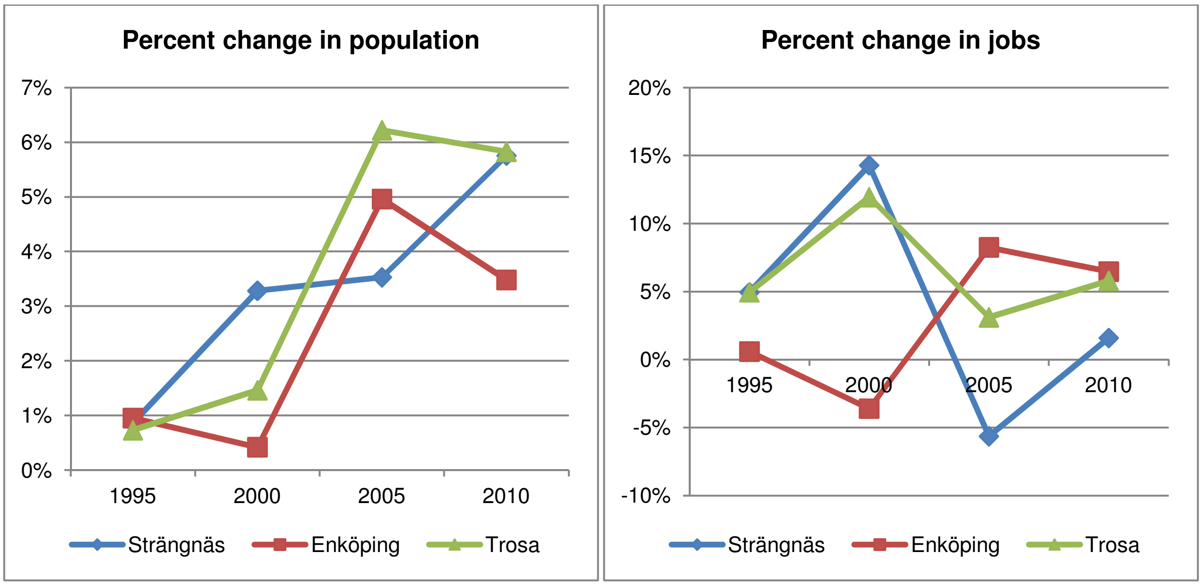


Figure 4.25: Change in population and jobs per 5 years: Strängnäs, Enköping, Trosa

Population growth was strong for both Strängnäs and Enköping (and also for Trosa), rising rapidly from 2000 in Enköping amidst line upgrades before stabilising around 4% and rising steadily in Strängnäs following high-speed introduction in 1997. Growth in jobs was mixed: Strängnäs achieved rapidly increasing growth up from 1995 to 2000, which declined to 2005 before recovering into positive territory by 2010. Enköping, after neutral-negative job growth up to 2000, experienced strong positive growth from amidst the line upgrades to high-speed and maintained positive growth up to 2010.

Job to population ratio

The job to population ratio, or degree of self-sufficiency, is presented in a 5-year time series for each of the study cities in Table 4.9. The larger cities enjoy a high job to population ratio, indicating a large number of jobs in relation to the number of residents and signalling inward commuting to the municipalities. Small-medium cities have a moderate-high ratio reflecting a greater degree of outward commuting. It has fallen slightly over the 15 year period in all high-speed served city cases, indicating higher growth in outward commuting relative to inward.

Table 4.9: Job to population ratio in study municipalities

Municipality	Job to population ratio				Change
	1995	2000	2005	2010	'95-2010
Eskilstuna	100%	98%	99%	98%	-2
Västerås	107%	106%	103%	104%	-3
Nyköping	94%	92%	93%	94%	1
Köping	107%	104%	107%	100%	-7
Arboga	102%	89%	88%	93%	-9
Sala	85%	78%	78%	81%	-5
Strängnäs	80%	83%	74%	71%	-9
Enköping	84%	76%	77%	78%	-5
Trosa-Vagn	64%	68%	67%	67%	3

Summary of regional effects by city groups

All cities gaining high-speed services experienced substantial growth in outward commuting since their introduction; larger regional cities within an hour's commuting time of Stockholm (Eskilstuna and Västerås) experienced the largest growth, of which a significant proportion is to Stockholm; the sustained levels of commuting and continually increasing growth reflects the willingness for residents to commute to a larger pool of jobs in neighbouring regions and signals the arrival of new residents prepared to commute from their new place of residence, a fact supported by positive population growth. Growth in inward commuting is visible but less pronounced and slower to emerge, evidence of a longer-term emergence of new jobs (and establishment of new firms) in formerly less accessible regions to which outside residents are now able to commute. Smaller cities within one hour of Stockholm (Enköping and Strangnäs) experienced strong growth in outward commuting (of which a high proportion to Stockholm), consistently positive population growth and variable but overall positive job growth.

Despite steadily increasing inward and outward commuting in small-medium outer regions (Köping and Arboga), overall population and job growth was negative or low in years prior to and immediately after the introduction of high-speed, possibly due to external factors such as the Volvo closure in Arboga in 1997. In recent years however, the trend was towards positive growth; it may require several more years of observation to realise the long-term effects.

Notwithstanding the influence of external factors, the rail supply improvements evidently have led to significantly increased commuting and appear to be having a positive influence on regional population and job growth, although they are only beginning to emerge.

4.4.3 Summary of longer-term effects over region

To study every city/locality in the Stockholm-Mälaren region to the same extent as the city group examples in the previous section would be too detailed for this thesis. The purpose of the analysis was to give a representative picture of the longer-term regional development effects that could be expected in small-medium sized cities situated within 1-1.5 hours travel time from Stockholm. The picture isn't necessarily the same for smaller cities, cities located considerably further away from Stockholm and cities without a direct high-speed connection. A summary of the effects studied in the examples above for municipalities affected by regional high-speed rail over a 15-year period (1995-2010) is given below in Table 4.10.

Table 4.10: Change in population, jobs, commuting in municipalities, 1995-2010

Municipality	Av travel time to Stockholm	Year 2010		Percentage change, 1995-2010 (%)				
		Population	Job-pop ratio	Popu-lation	Jobs	Commuting Inward	Commuting Outward	Job-pop ratio
Uppsala	0:39	197,787	95.9	7.8	22.1	76.8	38.1	3.0
Tierp	1:25	20,125	77.7	-0.2	-2.9	41.0	69.2	-10.1
Gävle	1:28	95,055	103.1	4.9	8.0	57.2	77.1	-0.4
Enköping	0:40	39,759	78.1	9.1	11.1	49.9	54.1	-5.4
Västerås	1:00	137,207	104.3	10.9	14.1	41.6	83.7	-2.3
Hallstahammar	1:23	15,175	82.0	-5.6	-5.6	37.5	33.7	-4.1
Köping	1:11	24,905	100.1	-4.7	-6.7	8.8	53.7	-7.2
Arboga	1:22	13,285	92.8	-8.7	-16.5	14.8	50.9	-8.7
Örebro	2:08	135,460	108.8	13.2	23.5	49.9	62.1	0.6
Hallsberg	1:35	15,275	102.4	-6.8	-1.4	23.3	11.6	4.2
Nykvarn	0:30	9,331	53.9	15.9	46.1	87.0	8.6	12.8
Strängnäs	0:48	32,419	71.1	13.1	9.6	30.3	60.4	-9.3
Eskilstuna	1:06	96,311	98.0	7.7	13.8	66.5	93.9	-2.2
Kungsör	1:28	8,089	76.2	-3.3	11.4	67.0	8.5	7.1
Flen	1:02	16,028	87.9	-7.0	-10.5	15.5	35.5	-6.3
Katrineholm	0:58	32,428	98.4	-2.5	-2.9	30.4	59.4	-3.7
Nyköping	1:05	51,644	94.2	6.0	14.4	56.8	41.0	0.4
Norrköping	1:20	130,050	100.8	5.1	7.0	36.8	123.9	-6.0
Linköping	1:52	146,416	109.6	11.5	18.2	60.8	69.1	2.1

Source: SCB (2012); Resplus (2012)

The largest city and closest in proximity to Stockholm, Uppsala, achieved strong growth in population and jobs, coupled with high growth in (particularly inward) commuting, reflecting the economic inertia of this populous city with a diverse economy and large university and its ability to attract commuters, new residents and businesses from Stockholm and neighbouring areas. The three next largest cities within 1-1.3 hours from Stockholm (Eskilstuna, Västerås and Norrköping) achieved strong growth in (particularly outward) commuting, and moderate growth in population and jobs. Eskilstuna and Västerås achieved higher population and job growth than Norrköping, due to the former two being within an hour's reach of Stockholm and able to attract a growing number of commuters, residents (and firms) from Stockholm.

The strong performance in these regions is also linked to their relatively large populations in the Stockholm-Mälaren region (95,000-140,000), meaning that they possess the preconditions (existing pool of labour, local businesses) for increased economic development in the wake of improved accessibility to other regional centres, most notably Stockholm. This is true also for the larger cities of Uppsala, Gävle, Örebro and Linköping, which have each reported strong population and job growth (albeit more modest for Gävle) despite the latter three being 1.5-2 hours journey time from Stockholm; the cities have been able to build on their already strong economic base and the improved accessibility to neighbouring regions (as well as Stockholm) has expanded their labour markets (reflected in commuting) and attractiveness to businesses.

Medium sized cities with populations 30,000-50,000 (Enköping, Strängnäs, Katrineholm and Nyköping) reported strong population and job growth, except for Katrineholm which reported slightly negative figures. Enköping and Strängnäs are well under one hour's travelling time of Stockholm as a result of supply improvements and consequently have experienced large rises in commuting. The larger more integrated cities of Enköping and Nyköping gained a similar proportion of inward commuters to outward commuters and the smaller more isolated cities of Strängnäs and Katrineholm experienced double the number of out- than in-commuters.

Small cities and towns with populations of less than 25,000 experienced mixed performance. In most cases there was an overall decline in population and jobs but, as the city group study revealed, the high negative growth occurred in earlier years prior to and amidst the upgrades to high-speed and had recovered to neutral or positive growth in subsequent years, evidence of the delayed impact of rail improvements on regional development, particularly for smaller cities. Cities on the Mälaren line (Köping, Arboga, Hallsberg, Hallstahammar) experienced moderate decline in population and jobs but growth in commuting with mixed patterns. The isolated and infrequently served city of Flen experienced negative growth, and Tierp, between Uppsala and Gävle on the East Coast Line, experienced marginal decline with higher outward commuting. Two municipalities that exhibited positive trends were the Svealand line cities of Nykvarn and Kungsör: Nykvarn, located on the periphery of Stockholm County, experienced a dramatic increase in population and jobs, accompanied by a very large increase (87%) in inward commuting. Kungsör experienced a strong increase in jobs accompanied by a large increase in inward commuting, but its population decreased marginally. An overall trend was for smaller inner cities (<1 hour from Stockholm) to outperform smaller outer cities (>1 hour from Stockholm), in inward commuting, population and jobs, evidence of a distance effect.

The job to population ratio (degree of self-sufficiency) averages around 100% in the larger centres and between 75% and 100% in small-medium centres, with the exception of Nykvarn (54%). In most cases, the ratio has slightly decreased, signalling the growing level of outward commuting relative to inward commuting. Combining this factor with the general increase in population across the Stockholm-Mälaren region, it is evident that people are moving into the regions and the majority of those are retaining their jobs in Stockholm (or other large centres) and opting to commute with the improved rail transport supply. Similar across-the-board job growth in the medium-large centres suggests businesses are relocating to the regional centres as a result of lower costs (or other non-market measures) but retaining their labour markets due to increased accessibility.

4.4.4 City specific studies on regional development trends

Based on dialogue with and visits to some municipalities in the region, three city case studies were briefly carried out. The purpose of the case studies is to look beyond general statistical measures of commuting, population and employment, upon which supposed regional effects are based, to gain a local-regional first hand perspective on the effects of high-speed rail and substantiate the inferred effects. The three case cities are indicated on the map below.

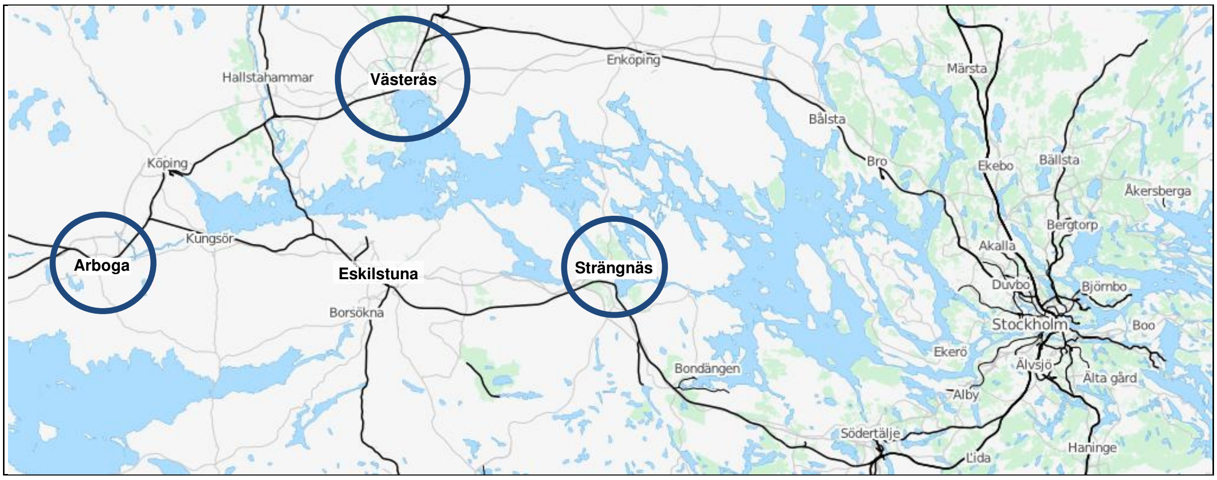


Figure 4.26: Case cities depicted on map (Map source: OpenStreetMap, 2012)

Västerås (Mälaren line)

The period 1997-2007 saw a large increase in inward and outward commuting that was much higher than expected; a reduction of 10-12% occurred over 2008-2009 due to poor economic conditions and reduced rail quality/supply; it subsequently increased in 2010 and, as of 2011, 13,000 commute in to and 10,000 out of Västerås, of which 1/3 are to/from Stockholm and of those 50% are by train. A target of double this figure by 2020 assumes travellers are twice as keen to use public transport as today and a high proportion are drawn from car. Commuting is important for several large companies (including ABB, Bombardier and ICA). The average migration to Västerås has for several years been around 800-1,000 persons but this recently increased to 1,500 persons; it is aiming for a population growth of 1,600 per year up to 2050 for a total population of 200,000. Commuting is recognised as an important precondition for regional development and, while there was previously little interest in establishing companies due to limited commuting, the recent trend has been for companies to locate in Västerås – a complete city with a full range of services – rather than, for instance, in a Stockholm suburb; workers are increasingly opting for a ‘smooth’ commute between Stockholm and Västerås.

The city is developing a ‘comprehensive plan’ for the station area with the aim of linking the station with the surroundings that includes rebuilding the station and developing commercial and residential areas around it. Three busy nearby roads will be rerouted to alleviate barrier effects between the station and city centre, and pedestrian and bicycle paths and green spaces will be introduced. Another aim is to improve the coordination between local public transport and rail services to enable combined public transport travel. It is worth noting that the interest in establishing businesses in the station area has increased as a result of the plan.

For the Mälaren line to achieve the required capacity, efficiency and robustness, assuming the full benefits of the Stockholm City Line project are reached, requires upgrades to Västerås rail yard (including expansion to four tracks) as well as capacity enhancement measures on the Mälaren line at Kallhäll and Tomteboda (Stockholm), each of which are planned by 2017. There is also a major investment planned to develop Västerås as a logistics node. (Strandman and Jonsson, Västerås stad, 2012)

Strängnäs (Svealand line)

As for other cities on the Svealand line, Strängnäs experienced a rapid increase in commuting following the line's opening in 1997, especially in outward commuting. Today approximately 6,500 commute out of Stängnäs municipality (shared between Strängnäs city and Läggesta-Mariefred), of which 4,500 travel eastward towards Stockholm; of these about half commute to Södertälje (mostly by car) and half to Stockholm, of which about 40% travel by rail. Of the 2,000 commuting in the westward direction, around 1,000 commute to Eskilstuna (of which 10-15% travel by train). The rise in (predominantly outward) commuting expanded Strängnäs and its volume of outward commuting is similar to Eskilstuna despite it being a larger city.

Both Strängnäs and Eskilstuna experienced population growth in the years coinciding with the opening of the line, although this increase is attributed to transport investments in general and not solely to the new railway; nonetheless it is acknowledged that without the railway important parts of development would have been lost. While the cities of Eskilstuna, Västerås and Enköping are the most important junctions for the distribution of goods in the Mälardalen region, Strängnäs also has a share of this sector that has become the main generator of new jobs; the movement of distribution centres (of food, car parts, etc) to Strängnäs and the other regions has occurred due to high rents and reduced flexibility in handling in Stockholm. It is worth mentioning that as it was not designed for goods traffic, only a small amount of freight (1-2 trains per day) is carried on the Svealand line.

Plans are underway to upgrade rail infrastructure around Strängnäs and redevelop the station as part of strategy to improve the capacity of the line, which is limited to one train per hour (with some additional trains in peak times that don't manage the same travel times) due to the presence of single track (from Läggesta) with passing loops. The project, which involves the construction of 7 km of double track and a new station, will permit trains to run half-hourly, thus doubling the current capacity; it is planned to be completed by 2017 at the same time as the Stockholm City Line project and upgrades to the Mälaren line. The station redevelopment plan proposes a central twin platform with overhead access and waiting area, three entrances (north, south and east), additional car parking for commuters and coordination of local buses with trains. It is to be developed exclusively as a travel area without commercial development due to space restrictions and its relatively close proximity to existing town centres that would likely suffer from any development around the station. (Nilsson, Strängnäs Kommun, 2012)

Arboga

Arboga views the developments and improvements to infrastructure around Lake Mälaren as important for its future development. The city experienced an economic setback in 1997 when the large company Volvo moved away from Arboga and around 1000 people moved away in the years following. However, the town was able to turn around this effect and today around 40% of its working residents commute to work in such neighbouring cities as Örebro, Köping, Västerås and Eskilstuna. As a result of improved accessibility, there are more opportunities for work, studies or leisure in those cities which can now be reached in less than half an hour by train. Around 30% of its workforce commutes to Arboga for work. It is interesting to note that Arboga is located near a junction of county borders over which travellers pass regularly; while borders have less meaning in a region like Arboga, the division of public transport by county can make it difficult for people travelling across county borders. (Marklund, 2012)

4.4.5 Supportive strategies for regional development

As the literature suggested, transport supply improvements that offer increased accessibility alone don't necessarily lead to an improved economic environment in all regions affected; in particular smaller and more remote regions tend to suffer at the benefit of larger economically dominant regions. This may have occurred to some extent in the Stockholm-Mälaren region, in which the larger centres of Eskilstuna and Västerås reported growth above smaller regions further away from Stockholm (e.g. Köping, Arboga and Hallsberg); it is however too early to confirm this effect since population and firm/job movements are long-term phenomena and reports from municipalities suggest positive effects. In any case, it is accepted that supportive strategies are necessary to ensure the positive impacts of transport supply improvements are felt. Complementary to the introduction of high-speed rail services, support strategies that have been enacted include the coordination of rail services with local public transport, station redevelopments, and relocation/establishment of public institutions in regional cities. A brief summary of each is given hereunder.

Coordination with local public transport

The linking of local public transport with high-speed regional rail, thus facilitating combined public transport travel, is considered an important strategy to improve accessibility between homes and workplaces through shorter journey times and effortless changes. It forms part of the station redevelopment plans for Västerås and Strängnäs and, based on these case studies, can be assumed to be a priority for all connected regional centres. In the case of Västerås, the 'Smartkol' project is developing a scheme with fewer bus lines with higher frequencies and changes to streets for improved bus movements with the aim to reduce travel times.

Station redevelopment

Station redevelopments are planned for Västerås and Strängnäs, as discussed in the city case studies section, with the aim to improve access and capacity and, in the case of Västerås, to link the station with the city and develop the area as an important commercial centre that is attractive for businesses to locate. High-speed stations in the Stockholm-Mälaren region are almost exclusively centrally located in cities and towns they serve; an exception is Södertälje Syd. As the literature confirms, centrally located stations have the highest potential to attract commuters and development, a useful prerequisite for regional development.

Establishment of public institutions

In addition to firms that have chosen to relocate to regional centres due to economic reasons, such as lower rents or location advantages, several public institutions have been established (or relocated from Stockholm) by governments in an attempt to offset the decline of industry jobs and bolster the regions. Relocated or newly established institutions include the defence services and the Swedish Energy Agency, which established in Eskilstuna in 1998 following the opening of the Svealand line and is expanding (Nilsson 2012). The Mälardalen University (Swedish: Mälardalens högskola) established in 1977 in Västerås and Eskilstuna hosts over 13,000 students and offers studies in fields of economics, health, education and engineering; it promotes its short distances between campuses and to/from Stockholm (MDH, 2012).

Networked cities: a need for supportive strategies

An expected effect of the development of transport infrastructures in the Mälaren valley was the formation of a system of cities along northern (Mälaren line) and southern (Svealand line) bands linked westward to the large regional city of Örebro. Despite a high quality road and rail system linking the cities with short travel times, traffic didn't develop between Eskilstuna and Örebro to the volumes expected and no significantly increased cooperation between the cities of Västerås, Eskilstuna and Örebro was observed. (Nilsson, 2012)

There is significantly more inter-city traffic on the (northern) Mälaren line than the (southern) Svealand line, particularly commuting from Stockholm to Västerås; this is related to the share and location of industry between the two corridors: Mälaren line cities have a greater share of industry and engineering than Svealand line cities, and the presence of double track favours that route; on the other hand, Eskilstuna and Södertälje have more industry than Västerås but the dominant industry city of Södertälje is also served by Western and Southern Main Lines. The diversity of industries between the cities could mean they have so far seen little benefit in cooperating extensively with one another, in contrast with the theory of networked cities that benefit collectively from mutual exchange of specialist industries and services. This network effect may still emerge but the observations suggest that while improved transport supply is a necessary precondition for the development of city networks, complementary measures that support increased exchange between regional centres may be required.

5.1 Melbourne-regional Victoria: overview

5.1.1 Geography, population and transport

Melbourne-regional Victoria, as it is referred to in this thesis, doesn't constitute a region in its own right but is broadly used to describe the region of the south-eastern state of Victoria that includes the capital city Melbourne and its surrounding regions that are considered accessible or potentially accessible to and from it, excluding distant rural areas; 'accessible' in this sense is the ability for people and goods to move between regions in reasonable time, thus implying a mutual dependency that constitutes a network of regions or cities.

The city of Melbourne, Australia, is the largest and overwhelmingly dominant in its region. With a population in excess of 4 million and growing, it outstrips its largest regional satellites by between 20 and 40 to 1, which are situated between 50 and 150+ kilometres from the capital. Reflecting its size and location, Melbourne is economically dominant in the industrial and services sectors, while the regions are mainly based around primary industries albeit with some manufacturing and a growing services sector in the larger regional centres. (RDV, 2012)

Transport links consist of roads and railway lines emanating radially from Melbourne. Roads are relatively direct and high-capacity, and rail and coach services operate with varying speed and frequency. Cross links between regional cities consist of minor roads and highways, and public transport links are few and infrequent, thus reinforcing the dominance of links between the regional centres and Melbourne over inter-regional city ones. Road is the dominant transport mode for both people and goods. Roads carry the bulk of freight along the main corridors to and from Melbourne and rail freight is concentrated in western regions (DoI, 2001).

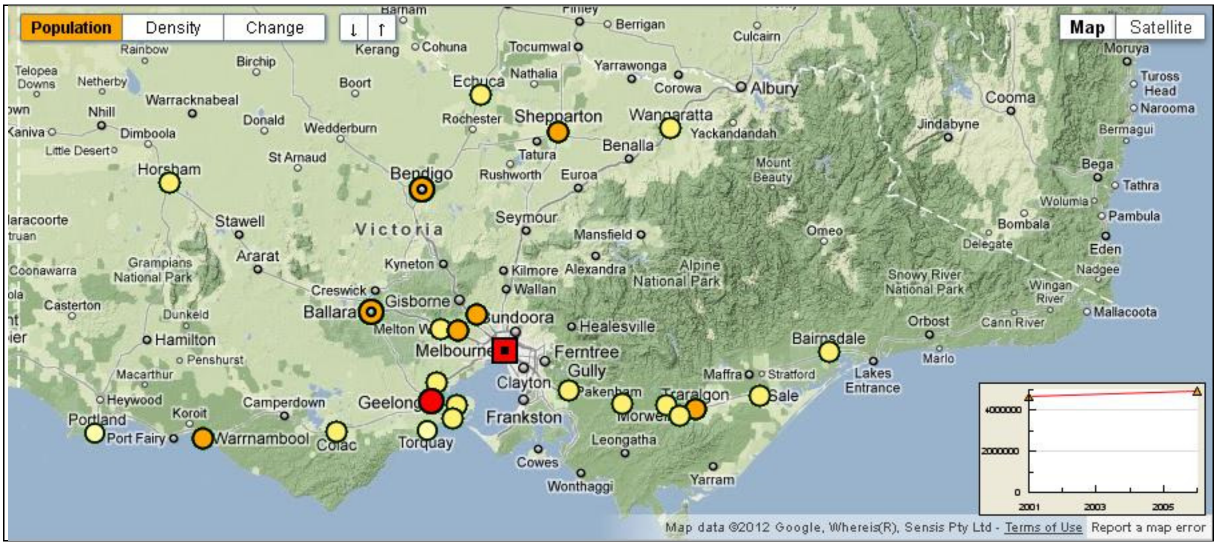


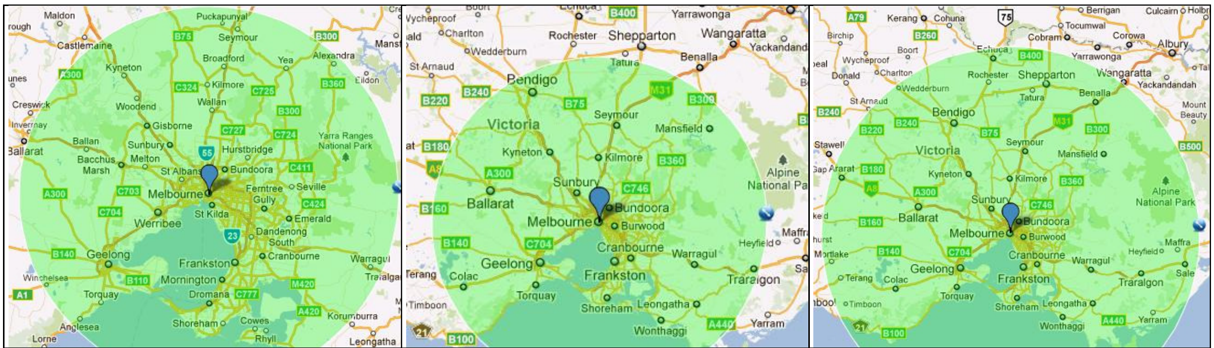
Figure 5.1: Melbourne-regional Victoria
Sources: City Population (2012) http://www.citypopulation.de/php/australia-victoria.php

Table 5.1 summarises population and distance from Melbourne of the important cities and towns in regional Victoria. Distance is 'road distance', which is considered the benchmark for travel time and accessibility. Figure 5.2 shows distance radii at 100, 150 and 200 km from Melbourne. By comparison, the population of metropolitan Melbourne is 4.14 million; the suburbs of Melton and Pakenham (listed below) are included. Population growth in regional cities since 2010 is between 1 and 2 % per year (DPCD, 2012).

Table 5.1: Melbourne-regional Victoria: city population and road distance from Melbourne

City / town	Dist. from Melbourne	Population Urban area	City / town	Dist. from Melbourne	Population Urban area
Ararat	205	7,169	Maryborough	168	7,692
Bacchus Marsh	58	13,261	Melton	45	35,490
Bairnsdale	282	11,282	Moe	135	15,582
Ballarat	115	78,221	Morwell	149	13,399
Benalla	211	9,129	Pakenham	62	18,808
Bendigo	151	81,939	Sale	214	13,336
Castlemaine	121	7,248	Seymour	110	6,063
Colac	152	10,857	Shepparton	189	38,773
Drouin	97	6,858	Sunbury	40	29,566
Echuca	221	12,358	Traralgon	164	21,960
Geelong	75	160,991	Wallan	59	5,410
Gisborne	53	6,398	Wangaratta	250	16,845
Horsham	301	14,125	Warragul	104	11,498
Kilmore	73	4,721	Warrnambool	265	28,150
Kyneton	85	4,286	Wodonga	319	29,710

Source: http://www.freemaptools.com/; ABS (2012) (2006 census figures)



100km from Melbourne	150km from Melbourne	200km from Melbourne

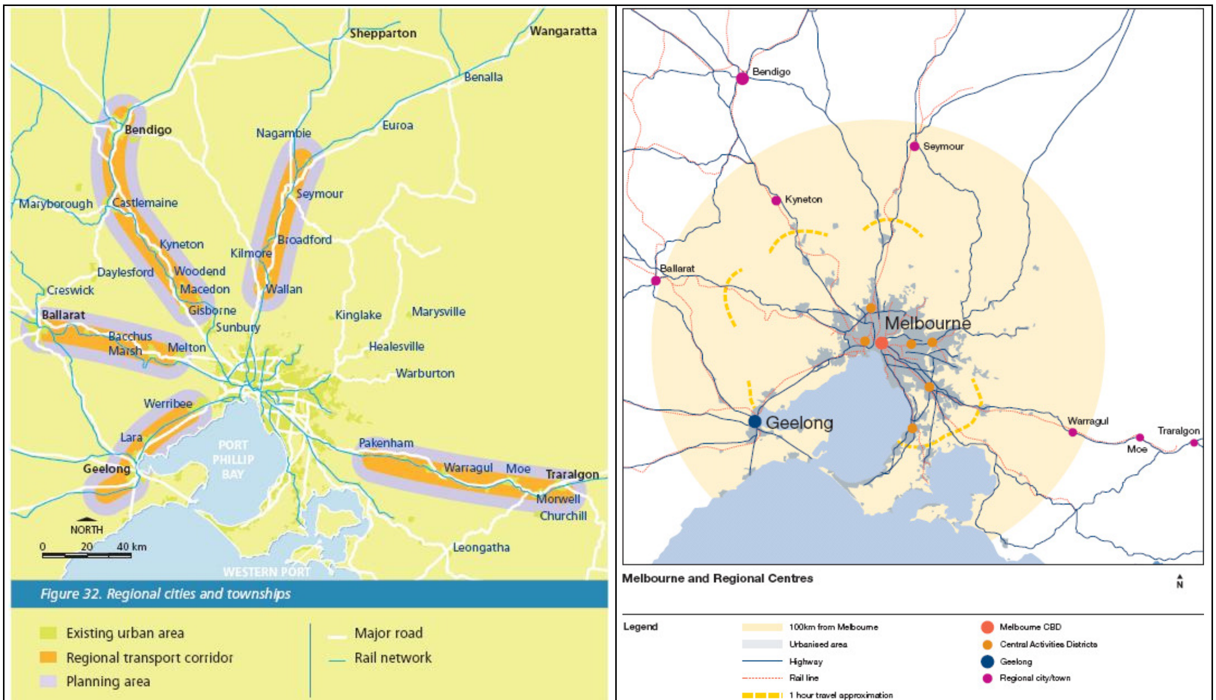
Figure 5.2: Distance radii from Melbourne
Source: Free Map Tools (Radius around Point) (2012)

Regional centres can be grouped into three types: large regional cities (>75,000 inhabitants: Geelong, Bendigo, Ballarat); small-medium regional cities (>10,000 inhabitants); and small regional cities and towns (<10,000 inhabitants). Small-medium cities and towns dominate the region, thus giving rise to a rather monocentric regional city structure; the Stockholm-Mälaren region in comparison has a greater share of larger cities and is more polycentric.

5.1.2 Growth challenges and regional development

Melbourne is under severe pressure from future population growth and regional development has been proposed as a means of absorbing some of this growth. While distance and existing transport links hamper efforts to achieve high levels of growth in regional Victoria, improved accessibility brought about by high-speed rail raises the potential for regional development. SGS (2010) propose a polycentric state with larger diverse regions linked by high-speed rail.

The current population of the Melbourne's metropolitan area is 4.14 million and is projected to grow to over 5 million by 2030 (DoI, 2002). The majority of the population resides in low density suburbs that are highly auto-dependent and fit the definition of 'urban sprawl', which necessitates extensive car-based travel between poorly linked residential and job locations and generates negative external effects (RCV, 2003). To counter urban sprawl, the concept of 'transit oriented growth' is being promoted; it aims to reduce the proportion of low density development by shifting development to inner and middle ring suburbs along public transport corridors and in 'activity centres' at key transport nodes, and establishing growth boundaries and protecting green areas (DoI, 2002). The policy was amended in 2008 to 'Melbourne @ Five Million' in view of increased population forecasts and includes a provision for extending urban growth boundaries; it emphasises a multi-city metropolitan area and supports a concept of 'networked cities' built on improved links between Melbourne and regional Victoria (DPCD, 2008). The regional development planning concepts are depicted in Figure 5.3.



Melbourne 2030: networked cities Source: DoI (2002)	Melbourne @ 5 million: Regional Centres Source: DPCD (2008)

Figure 5.3: Regional development strategies: Melbourne-regional Victoria

Among various regional growth strategies, the policy framework has been supported by two notable rail transport investments designed to improve accessibility between Melbourne and regional Victoria: the 'Regional Fast Rail Project' (section 5.2.1) and 'Regional Rail Link'.

5.2 Melbourne-Victoria regional rail corridors

5.2.1 Railway network and infrastructure

Regional and country rail services in regional Victoria are served by a network of rail lines emanating from Melbourne, as depicted in Figure 5.4. In addition to rail services, there is an extensive coach network that occasionally replaces rail services and provides peripheral links between some of the regional centres. The railway network is predominantly single track with long passing loops and some double track sections near Melbourne and is built to broad gauge 1,600 mm (5 ft 3 in); interstate main lines are however standard gauge 1,435 mm. Outside the Melbourne suburban rail zone, all lines are non-electrified and trains are diesel locomotive-hauled (freight and some passenger) or diesel multiple unit (passenger). Signalling is a mix of British route signalling and American speed signalling and upgraded lines are equipped with Train Protection and Warning System (APWS), which is deployed across the UK passenger rail network and permits operation up to 160 km/h. (Vicsig.net, 2012; Chadwick, 2006)

All regional lines terminate at Melbourne's Southern Cross station, a terminus for regional and interstate services. In suburban areas of Melbourne, regional trains share track with the city's metropolitan commuter services, which limits the capacity of the infrastructure in peak periods and imposes speed restrictions in built up areas. There is a project currently underway (the 'Regional Rail Link') to construct a dedicated bypass section for regional trains between central Melbourne and the western regional lines. The predominantly passenger traffic lines also carry a limited number of freight trains, despite freight transport being overwhelmingly road-based: rail holds a 15% market share of interstate and local interregional freight (VFLC, 2010). Rail freight is mostly agricultural with a limited amount of container and quarry.

Figure 5.4: Victorian railway network
Source: partly modified from Wikipedia (2009)

Figure 5.5 depicts the rail network of Melbourne-regional Victoria schematically, indicating lines, stations and maximum permitted speeds for passenger trains.

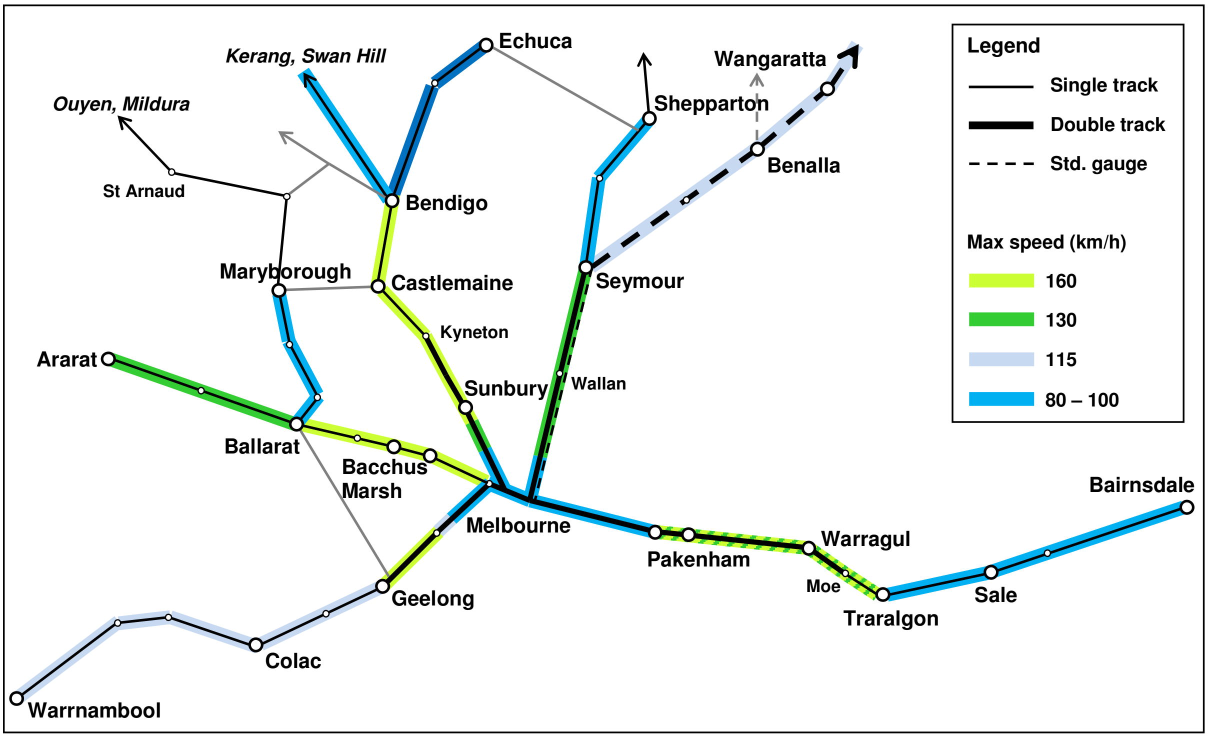


Figure 5.5: Melbourne-regional Victoria passenger rail network map
Source: constructed from V/Line (2012) and vicsig.net (2012)

The majority of regional and country lines were constructed in the decades following 1850 to meet a rapidly growing demand for passenger and freight services; the rail network reached a peak in the early 1940s but steadily declined thereafter with the closure of branch and cross-country lines up to the 1980s. The 1990s saw further reductions to services and privatisation but a turnaround occurred in the 2000s with progressive improvements to infrastructure and services, accompanied by increasing passenger traffic (Hearsch, 2007). The most significant improvements came as a result of the 'Regional Fast Rail Project', undertaken between 2000 and 2006, which delivered reduced travel times and enhanced frequency and safety.

The 'Regional Fast Rail Project' involved the upgrade of 500km of track, installation of new signals and the Train Protection and Warning System, upgrade of level crossings, delivery of new trains and development of new timetables for improved services. Track and signalling upgrades permitted 160 km/h operation of the new trains from 2006 on the Geelong, Ballarat and Bendigo lines. The project received criticism due to high costs, lack of travel time savings and the removal of one track from part of the Bendigo line; minimum journey times are based on one express "flagship" service per peak period but average travel times are significantly (30%) longer such that travel time savings are perceived as minimal (Moynihan, 2006). Three years on, the project had come to be seen as a success, boasting high passenger growth and contributing to regional development (Dowling and Puchalski, 2009). It demonstrated that modest time savings with improved frequency and punctuality generate significant passenger growth and that signified the potential of further supply improvements.

5.2.2 Regional rail services

Regional passenger rail services in Melbourne-regional Victoria operate along railway lines of the same name (and final destination) radiating from Melbourne (depicted in Figure 5.5). They can be broadly grouped into inner regional lines: Geelong, Ballarat, Bendigo, Seymour and Traralgon; and outer regional lines that continue or branch from these termini. The outer regional lines are typically a mix of rail and coach services, with train services having been only recently reintroduced on the entirety of some lines. All services are operated by V/Line.

Table 5.2 summarises the service data between Melbourne and the important regional cities on the regional lines for a Monday-Thursday timetable. Travel time is divided into shortest time (representing fastest inter-city express services) and average time (considering all direct services); departures are averages of to/from Melbourne. Peak hour frequencies do not differ considerably from average frequencies: slightly greater for inner services (which are already within one hour) and almost identical for outer services (which are evenly scattered through the day and not clustered at peak times). A summary of the rail services is given in Table 5.2.

Table 5.2: Summary of service data between Melbourne and key regional cities (Mon-Thurs)

Line	Station	Dist to Melb (km)		Travel time (hrs)[3]		Departures[3]	
		Road[1]	Rail[2]	Min	Avg*	Deps	Freq
Geelong	Geelong	75	75	0:49	1:01	31	0:37
Warrnambool	Colac	152	155	1:56	2:10	3.5	4:50
	Warrnambool	265	269	3:13	3:25	3	5:46
Ballarat	Bacchus Marsh	58	53	0:38	0:50	22.5	0:44
	Ballarat	115	122	1:05	1:23	18	0:55
Ararat	Ararat	205	213	2:15	*2:49*	6	1:58
Maryborough	Maryborough	168	180	2:12	*2:35*	6	2:40
Bendigo	Sunbury	40	40	0:32	0:39	24.5	0:41
	Castlemaine	121	127	1:07	1:32	18.5	0:54
	Bendigo	151	164	1:27	1:56	18.5	0:54
Echuca	Echuca	221	252	2:45	*3:34*	7	1:46
Swan Hill	Swan Hill	341	345	4:19	*4:41*	4	2:43
Traralgon	Warragul	104	102	1:25	1:36	17.5	0:54
	Traralgon	164	160	2:03	2:18	17.5	0:54
Bairnsdale	Sale	214	208	2:42	*3:00*	4	3:47
	Bairnsdale	282	277	3:37	3:46	3	5:40
Seymour	Wallan	59	47	0:38	0:45	16.5	1:00
	Seymour	110	102	1:10	1:25	20	0:49
Shepparton	Shepparton	189	185	2:24	*2:39*	5	2:28
Benalla / Albury	Benalla	211	197	2:05	2:28	6	2:36
	Wangaratta	250	236	2:31	*2:55*	6	2:36
	Wodonga/Alb.	319	304	3:30	*3:52*	4	3:36

*Average times in *italic* represent a mix of train and coach services
Sources: [1]www. freemaptools.com/; [2]Vicsig.net (2012); [3]Compiled from V/Line (2012)

The inner regional lines (Geelong, Ballarat, Bendigo and Traralgon), each of which benefited from recent line upgrades (maximum 160 km/h line speed) and improvements to services, run with a frequencies of under one hour and with reasonable journey times. There is, however, a marked difference between the minimum and average travel times, the average being 25-30% greater than the minimum, except on the Traralgon line. This reflects the limitation of the line improvements in overcoming capacity constraints to deliver shortest possible journey times to all but 1-2 peak hour services in each case. Notwithstanding modest travel time reductions gained with express inter-city services over stopping-all-stations services, capacity constraints include the coordination with Melbourne commuter train services and, more importantly, the extent of single track line with lower permissible speeds on passing loops. The Traralgon line on the one hand is double track over much of its length, which improves capacity and reduces the difference between minimum and average travel times; on the other, it traverses a larger suburban area on shared track with commuter services than the other upgraded lines, which reduces speeds, forces more frequent stopping and increases average travel time.

The Ballarat and Bendigo lines are single track over a significant proportion of their lengths. The majority of the Ballarat line is single track except for short crossing loops at Rockbank and Melton stations, passing loops between Melton and Bacchus Marsh stations and Bacchus Marsh and Ballan stations, and a long crossing loop at Bungaree (old line prior to upgrade). The Bendigo line is double track between Melbourne and Kyneton and single track beyond, which was previously double track prior to its dismantling and partial conversion to several passing loops as part of the 'Regional Fast Rail' project. The large extent of single track is reflected in the difference between minimum and average times for the final destinations: 18 minutes for Ballarat and 29 minutes for Bendigo. For the Seymour line, it is marginally less than for Ballarat at 15 minutes; a possible reason for this is the coordination with commuter trains for the extensive 30 km section of shared track between Melbourne and Craigieburn.

The outer regional lines have a much reduced frequency ranging from under 2 hours (Ararat, Echuca) to in excess of 5 hours (Warnambool, Bairnsdale). Several of the lines share services with coach for all or part of some trips which incurs additional travel time. All of the services run on predominantly single track line with maximum speeds of between 100-115 km/hr. It is worth noting that several of the services were only recently reintroduced after being closed in the 80s and 90s: Ararat and Bairnsdale in 2004, Echuca and Swan Hill in 2006, Maryborough in 2010. It is possible that resurgence in rail travel may spawn future additional services. Due to their low frequencies (beyond what is acceptable to commuting ≤ one hour) and long travel times to/from Melbourne (>2 hours), the outer regional lines have more the characteristics of interregional links than regional; the purpose is evidently for occasional business and leisure.

Accessibility by travel times

Accessibility based on travel times can be represented graphically in the form of isochrones of standard time intervals. The three intervals used are 60 minutes (generally accepted limit for daily commuting), 90 minutes (may be acceptable for commuting depending on distance from home/workplace to station and 120 minutes (acceptable for occasional 2-3 times a week commuting and leisure trips). Accessibility according to travel time is depicted in Figure 5.6 (based on average travel time) and Figure 5.7 (based on minimum travel time).

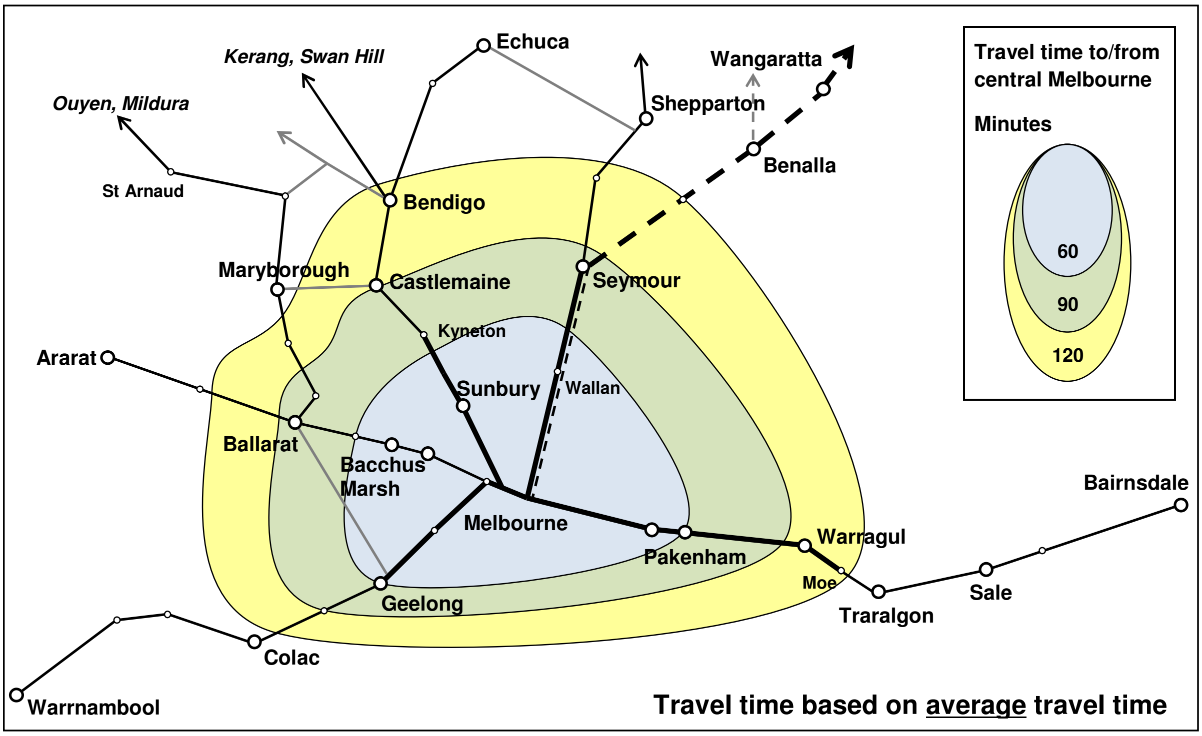


Figure 5.6: Accessibility by travel time to/from Melbourne based on average travel time

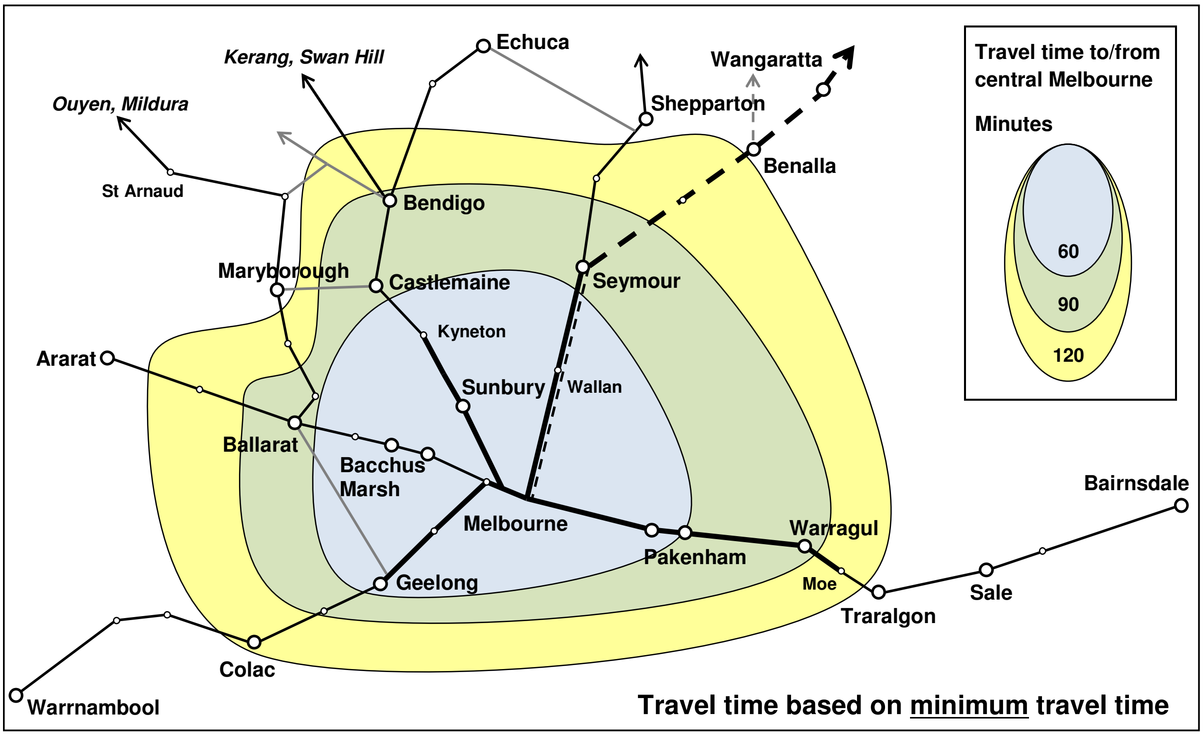


Figure 5.7: Accessibility by travel time to/from Melbourne based on minimum travel time

Service characteristics and trains

A summary of the service characteristics of each line is given in Table 5.3 and a description of train types in Figure 5.8. (Sources: V/Line, 2012; Vicsig.net, 2012)

Table 5.3: Summary of services on each regional line

Line Service	Express-IC, Stopping (from Mel / to Mel)[1]	Trains[2]	Max speed (km/h)	Track configuration[3]
Geelong	12 / 11 exp, 19 / 19 all	S, V, N/H-loco	160	Double
Ballarat	10 / 10 exp, 8 / 6 all	S, V, H-loco	160	Single
Bendigo	9 / 9 exp, 10 / 9 all	V, S, H-loco	160	D -Castle, S
Seymour	6 / 10 exp, 14 / 16 all	S, V, N/H-loco	130	Double
Traralgon	4 / 5 exp, 12 / 13 all	S, V, N-loco	160 / 130	D -Moe, S
Warrnambool	4 (1C) / 3	N-loco	115	Single
Ararat	7 (3C) / 6 (3C)	S, V	130	Single
Maryborough	6 (5C) / 6 (5C)	V	100	Single
Echuca	7 (6C) / 7 (6C)	V	75	Single
Swan Hill	4 (2C) / 4 (2C)	N-loco	90	Single
Bairnsdale	3 (1C) / 3 (1C)	N-loco, V	100	Single
Shepparton	8 (5C) / 8 (5C)	N-loco	100	Single
Albury	3 / 4 (1C)	N-loco	115	S -Seymour, D

[1]exp = express/fast inter-city services; all = stopping all stations; (#C): no. of coach services
[2]S: Sprinter diesel railcar; V: VLocity high-speed DMU; N/H-loco: locomotive-hauled cars
[3]D = double track; S = single track with passing loops

Sprinter high-speed diesel railcar	VLocity high-speed diesel DMU	Locomotive-hauled cars
Capacity: 90 economy (113 max)	Capacity: 140 (2 car), 216 (3 car)	Formation: 3-5 cars
Maximum speed: 130 km/h	Maximum speed: 160 km/h	Maximum speed: 115 km/h
Entry into service: 1995	Entry into service: 2005-06	Entry into service: 1980s

Source: Vicsig.net (2012): Current Passenger Rolling Stock

Figure 5.8: Train types serving Melbourne-regional Victoria

The upgraded (inner) regional services use more modern and versatile rolling stock capable of higher speeds and faster turnarounds. The outer regional services use either car-powered or older locomotive-hauled trains where requirements on speed and turnaround are less onerous; significantly lower demand and a higher proportion of leisure travellers reduce requirements for comfort and modern services in trains.

5.2.3 Recent performance and rail traffic development

Passenger traffic has been steadily increasing in recent years as a result of improvements to busier regional services brought about by the 'Regional Fast Rail' project which, in the wake of its success, has stimulated further investments in rail. The reintroduction of long-distance regional services has contributed marginally to this growth, although this seems to have been motivated more by regional growth objectives than transport demand.

No comprehensive study on the effects of the project's improvements has been identified but the growth in passenger traffic has been documented in V/Line annual reports for key lines. The growth in patronage by line is summarised in Table 5.4 and plotted in Figure 5.9 (number pass.) and Figure 5.10 (growth). The Traralgon line is referred to as the 'Gippsland' line and the region served by the line is commonly known as the La Trobe Valley.

Table 5.4: Growth in patronage by line (millions of passengers)

Year / Line	Geelong	Ballarat	Bendigo	Gippsland	Seymour	Total
04-05	1.84*	1.35	1.32	0.85	0.99	7.25
05-06	2.03*	1.37*	1.47*	0.82*	1.05	7.64
06-07	2.57	1.88	2.20	1.05	1.15	9.72
07-08	3.08	2.39	2.78	1.54	1.21	11.96
08-09	3.38	2.68	3.06	1.77	1.17*	13.17
09-10	3.47	2.82	3.15	1.91	1.22	13.71
10-11	3.77	3.10	3.36	1.95	1.32	14.65
Growth	105%	130%	155%	129%	33%	102%

*Periods of major track upgrade works
Source: V/Line Annual Reports 04-05 to 10-11

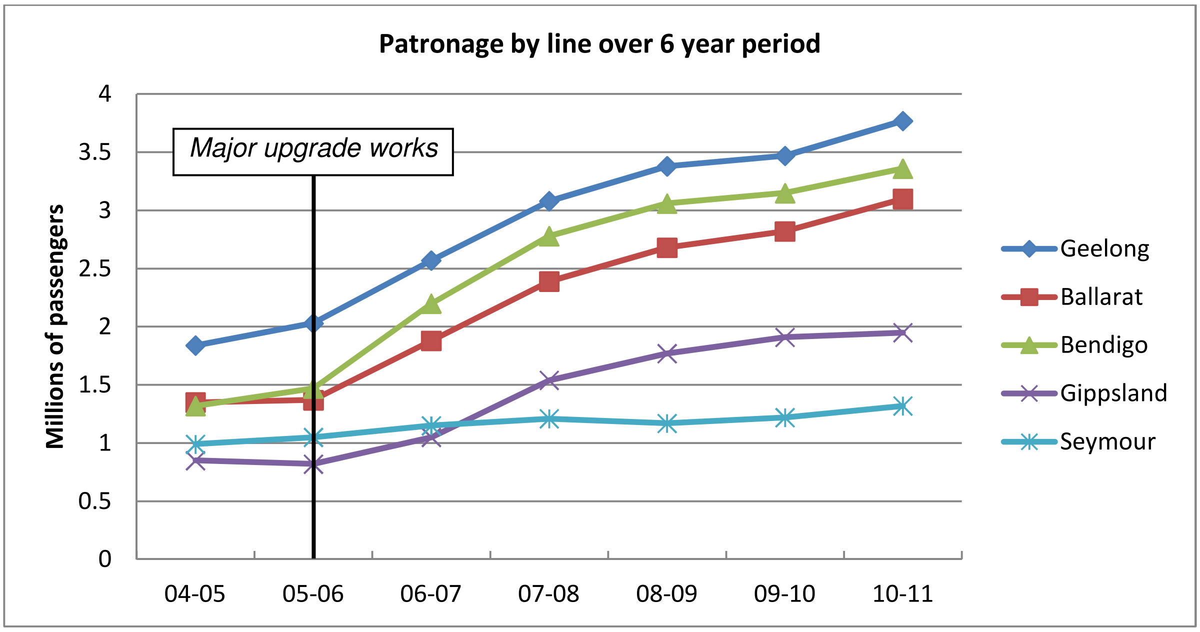


Figure 5.9: Growth in rail patronage 04-05 to 10-11

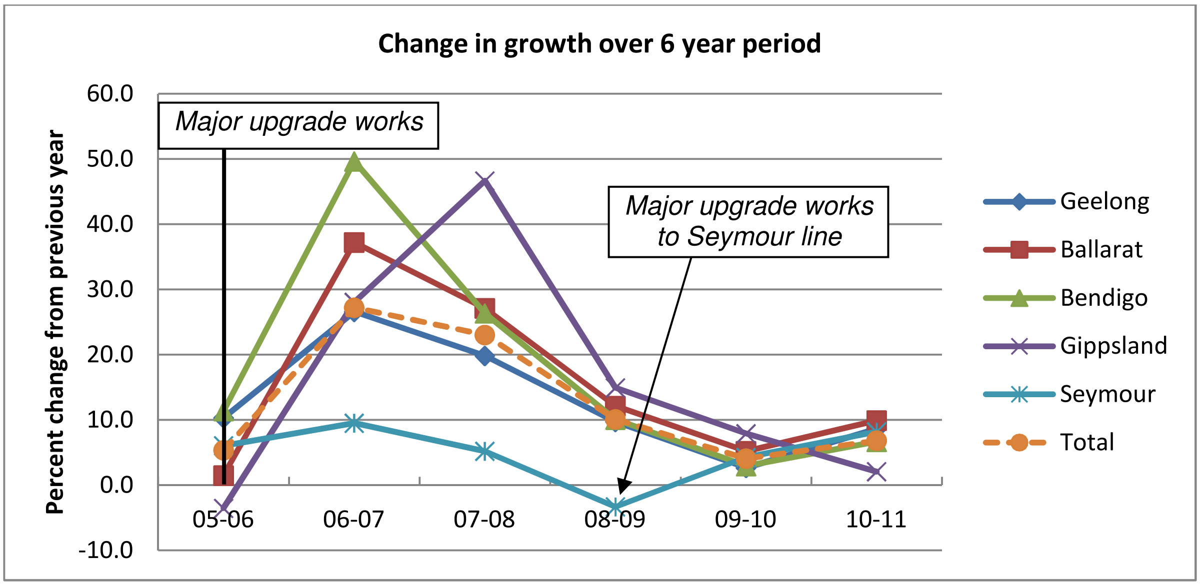


Figure 5.10: Change in growth in rail patronage 04-05 to 10-11

The graphs indicate continuously positive growth following upgrades on the majority of lines in the period 2005-06, with a maximum growth increase reached 1-2 years after the upgrades. In addition to supply improvements, ticket prices were cut on average by 20% in 2007 and remained at or below CPI in subsequent years; punctuality and reliability have been relatively stable. The charts clearly show the effect of the supply improvements on ridership and offer an insight into the sorts of gains that might be expected with further supply improvements, also applicable to the outer regional lines which achieved a more modest growth. Population growth (depicted in Figure 5.11) correlates positively to improvements to rail services in the regions, although it is probably too early to draw conclusions on long-term regional effects.

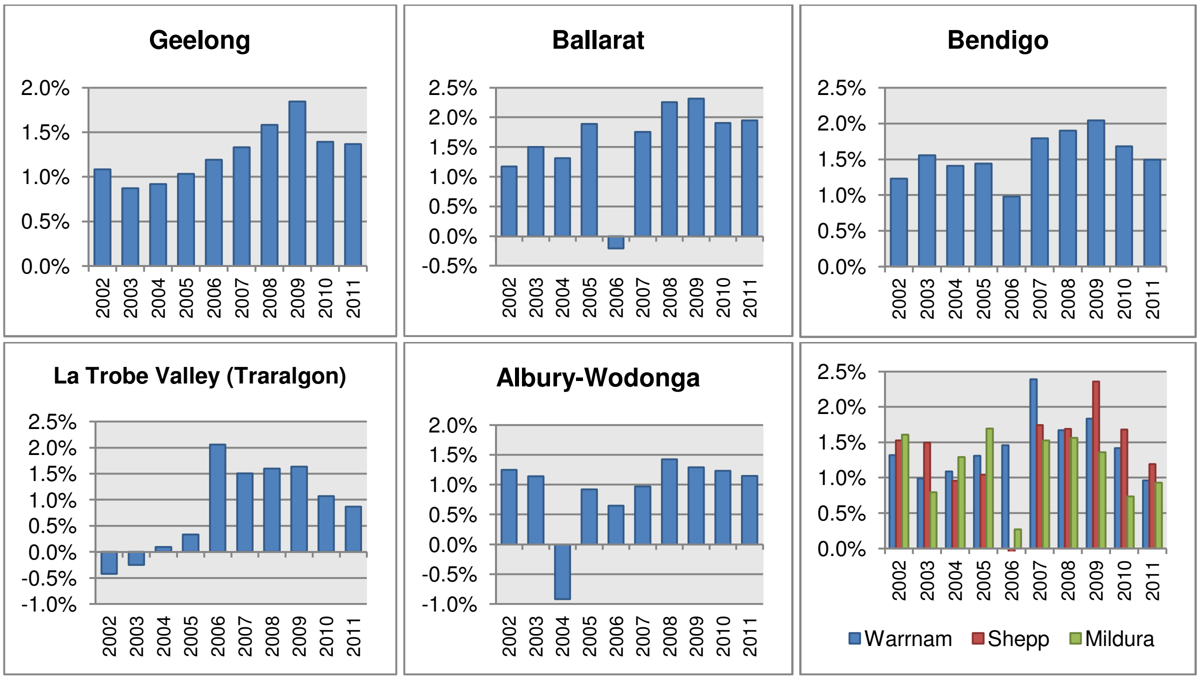


Figure 5.11: Population growth in regional cities, 2002-2011
Source: DPCD (2012)

5.3 Possibilities for high-speed rail in Melbourne-regional Victoria

The previous two sections presented a regional overview of Melbourne-regional Victoria and the regional rail services in operation, noting recent improvements that have contributed to an already solid network with steadily growing patronage. This section attempts to build on the recent success by proposing more radical network and service improvements it is anticipated will lead to significantly increased growth in rail travel over a wider geographic range, and in doing so, stimulate development of regions and influence settlement patterns in favour of the regions and away from Melbourne. The proposals draw on knowledge from the Stockholm-Mälaren region study, which has demonstrated the possibility for regional high-speed rail to enable commuting over a wider geographic area and generate economic growth in formerly less-accessible regions, and relevant literature that offers guidance on the preconditions for regional development. This section deals with the short-term affects that can be gained with supply improvements; the longer-term regional effects are addressed in a subsequent section.

5.3.1 Basis for rail supply improvements

Section 2.1 identified travel time as the most important factor in the generation of new travel but acknowledged service frequency as a significant factor (particularly for shorter distances) as well as fare price and comfort. Fare price and comfort will not be considered in any detail in this study as it is assumed that fare price is set to achieve a balance between affordable commuting and revenue requirements and that a modern vehicle fleet is capable of providing an acceptable level of comfort; price and comfort are nonetheless acknowledged as important factors in attracting car drivers. Reducing travel time shall be the focus of the improvements with frequency an important secondary consideration. To permit travel time reductions for a high proportion of trips requires higher operating speeds via infrastructure improvements and associated capacity enhancement measures, which shall be discussed in a subsequent section. This study assumes some typical target speeds that fit the definition of 'fast' and 'high-speed rail' and which have been employed in the Stockholm-Mälaren region. More importantly, the target speed should reflect the acceptable travel time for journeys based on their purpose: up to one hour for inter-city commuting, up to two hours for occasional (e.g. bi-weekly) trips and 2-3 hours for weekend leisure trips; and be faster than road transport.

Upgraded 'fast' regional services in Melbourne-regional Victoria operate with a maximum speed of 160 km/h, which is considered fast by traditional rail standards but falls short of the general definition of high-speed: 200 km/h for upgraded lines and 250 km/h for newly built lines (UIC, 2012). Upgraded lines in the Stockholm-Mälaren region are built for a maximum speed of 200 km/h. It is therefore reasonable to define 160 km/h operation as 'fast' and 200-250 km/h operation as 'high-speed'. The study will consider the travel time and accessibility implications of increasing the speed of outer regional lines to 160 km/h (existing for the inner upgraded regional lines), 200 km/h and 250 km/h, which is typically applicable to end-point inter-city services of between 300 and 600 km and possibly beyond what could feasibly be implemented for regional high-speed rail.

The different speed scenarios will be based on existing alignments, so that the rail distance is unchanged. This is reasonable to assume for speeds of 160 km/h, for which upgraded lines have been increased to whilst retaining their existing alignments, and 200 km/h, which might involve occasional smoothing of curves but would otherwise retain the current alignment. For 250 km/h, more onerous geometric requirements may require extensive sections of track to be rebuilt, although this is speculative and dependant on the geometry and stability of the current track; in any case, the new alignment won't vary considerably from the existing.

5.3.2 Determination of travel times

New travel times based on upgrades achieving higher maximum line speeds are determined approximately from average operating speeds that are derived empirically from timetabled travel times in respect of their maximum line speeds.

For 200 km/h maximum line speed, average speeds are calculated for services on upgraded lines in the Stockholm-Mälaren region to produce a representative average speed; travel times are based on minimum journey times in order to capture the maximum representative speed of fast (mostly stopping) services. The calculation of trip speeds is tabulated in Appendix 2. The distance-weighted average including all stops is 121 km/h and maximum average speeds are about 130 km/h for trips of around an hour from Stockholm (i.e. Eskilstuna and Västerås); the upper average (hourly trip) speed of 130 km/h is applied to Melbourne-regional Victoria services, which corresponds to an average speed/maximum speed ratio of 0.65. For 250 km/h line speed, for which there is no base data to estimate the average speed, a slightly reduced average/maximum speed factor of 0.6 is assumed, yielding an average speed of 150 km/h.

In each of these two 'high-speed' cases, a special situation exists for the Traralgon and (by extension) Bairnsdale lines: as previously mentioned, the Traralgon line traverses some 30 km of suburban area in Melbourne's extensive eastern metropolitan zone, sharing line with commuter services and is subject to speed limitations (maximum 80-100 km/h) and frequent stopping, resulting in an average speed of 60 km/h; thus there is limited scope to significantly reduce travel time through this zone. The proposed improvements do however envisage some increase in speed and assume an increase from 60 to 80 km/h through capacity enhancement measures, such as the addition of crossing loops at stations and timetable improvements, and less frequent stopping; this equates to a time gain of around 15 minutes, which is added to the calculated travel times for all stops on the Traralgon and Bairnsdale lines.

For the application of 160 km/h maximum line speed to the outer regional lines, the average speed is calculated for services on upgraded lines in regional Victoria (at end destinations) to gain a representative average speed that is applied beyond the existing upgraded lines to the non-upgraded outer lines to be improved. Average speeds are based on minimum travel time in order to represent fast inter-city/express services that are likely to serve the outer regions. The average rail speed is about 115 km/h for the fastest destinations (Ballarat and Bendigo) and it is assumed the upgraded outer regional services will achieve an even higher average speed due to longer distances between fewer stops; an average/maximum speed factor of 0.75

equates to an average speed of 120 km/h, which seems appropriate. Average speeds are lower on the Traralgon line (due to lower speeds and stopping through the extensive suburban area and regular stopping after) and the Seymour line (due to a maximum permitted speed of 130 km/h) and are excluded. The revised travel time for an upgraded outer regional line is the fast travel time to the final destination of the already upgraded inner line plus the additional time over distance based on average speed (120 km/h). The calculation of trip speeds is tabulated in Appendix 3. The Seymour line retains its current maximum speed of 130 km/h (following recent upgrades that did not achieve an improvement to 160 km/h) and all coach services are replaced with fast rail services.

A summary of the speed enhancement scenarios is given in Table 5.5.

Table 5.5: Summary of speed enhancement scenarios

Maximum line speed	Upgraded lines	Basis for travel time	Average line speed	Avg / max speed factor
160 km/h	Outer lines: Warrnambool, Ararat, Maryborough, Echuca, Swan Hill, Shepparton, Bairnsdale, Albury	Regional-Victoria upgraded inner lines Minimum travel times	120	0.75
200 km/h	Inner lines: 200 km/h Outer lines: Current, 160, 200 kph	Stockholm-Mälaren Minimum travel times	130	0.65
250 km/h	As for 200 km/h	Extrapolated 200 km/h	150	0.60

5.3.3 Accessibility by travel time for increased line speeds

Accessibility based on travel times is presented graphically in isochrones of standard time intervals for each of the three speed scenarios. The three time intervals used are 60 minutes (generally accepted limit for daily commuting), 90 minutes (may be acceptable for commuting depending on distance from home/workplace to station) and 120 minutes (acceptable for occasional 2-3 times a week commuting and leisure trips).

A basic interpretation follows each scenario with a more detailed discussion at the end of the section. Tabulated travel times are presented in Appendix 4 and travel time gains are plotted in Figure 5.18. Figure 5.12 is a reference case that compares current average travel time with current minimum travel time without speed enhancements. In effect, it represents upgrades to inner lines so that they are capable of achieving minimum times (on average or for a majority of services). The effect is significant, bringing Ballarat, Castlemaine and Seymour close to one hour from Melbourne, and Bendigo and Warragul to within 1.5 hours from Melbourne.

Increase to 160 km/h maximum speed on outer regional lines

This speed scenario, depicted in Figure 5.13, is based on attainment of minimum travel times on inner regional lines but without additional speed enhancements. It compares the minimum travel times (corresponding to current speeds for rail services) on outer lines to those with an increase to 160 km/h.

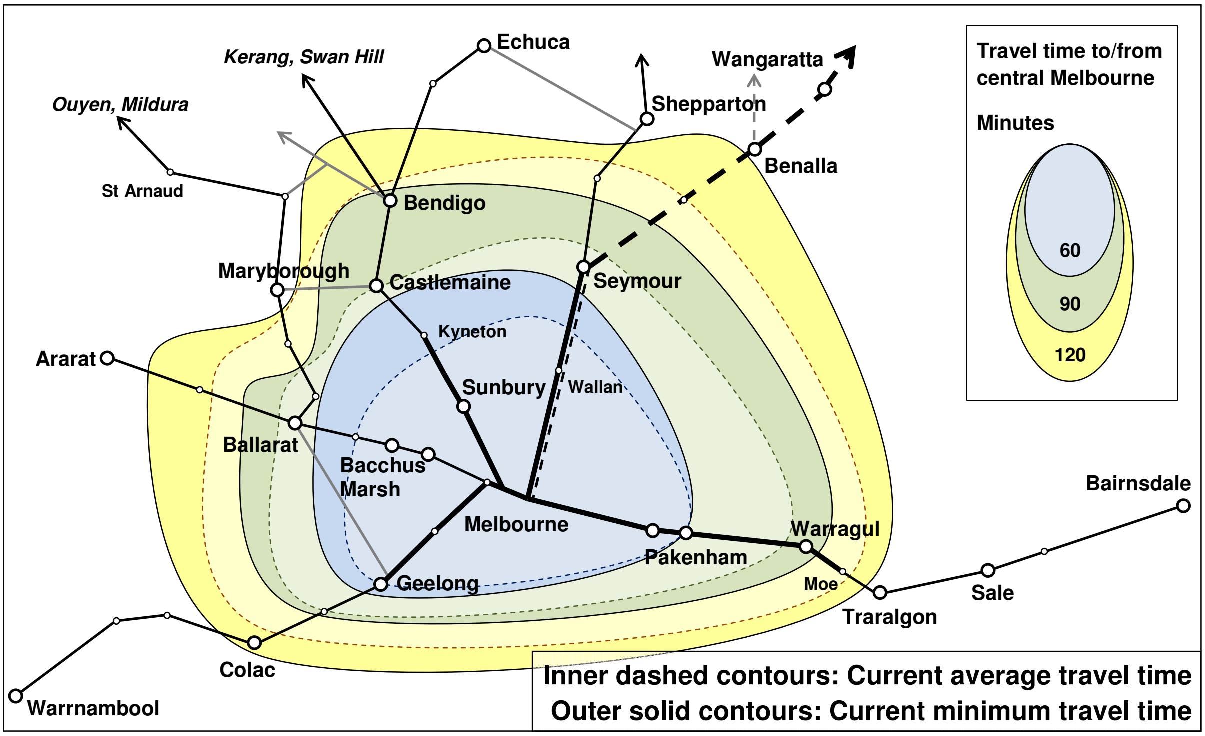


Figure 5.12: Accessibility to/from Melbourne: Minimum travel time versus average (reference)

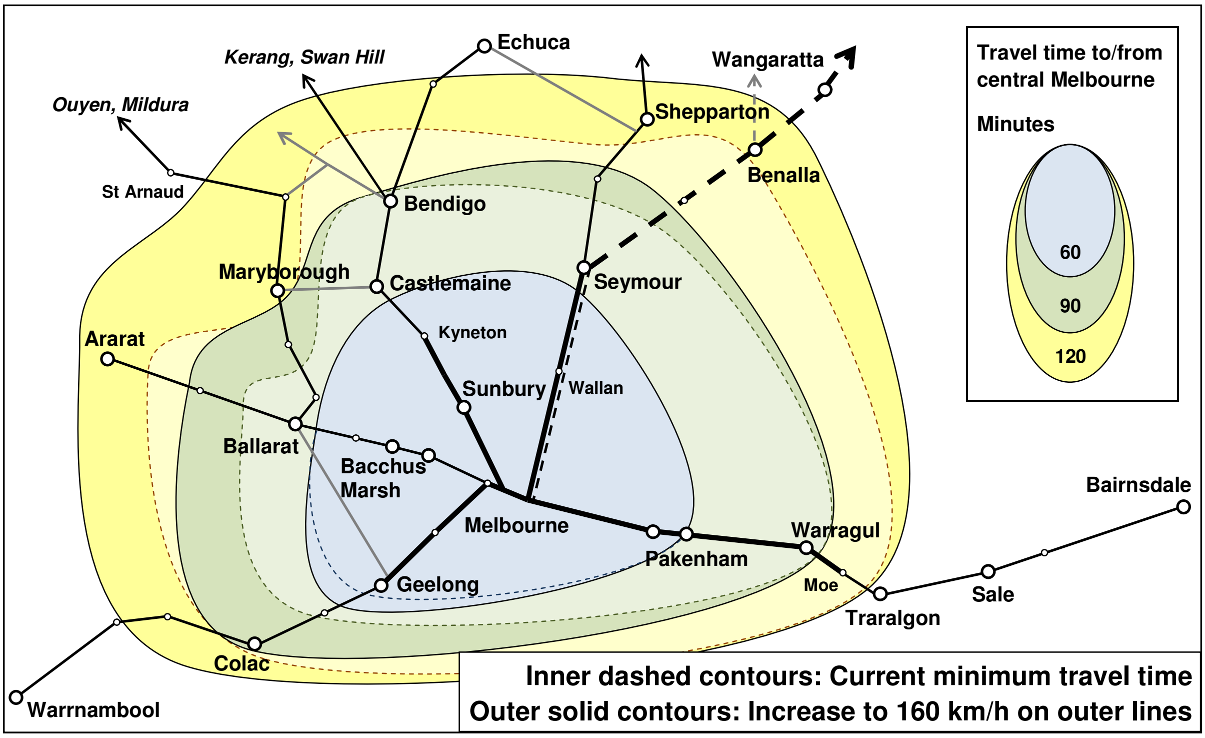


Figure 5.13: Accessibility to/from Melbourne: Current; upgraded to 160 km/h on outer lines

Upgrading the outer lines to 160 km/h does not affect journeys within one hour's access from Melbourne but reduces the time to several outer regional centres. Colac and Maryborough are brought to within 1.5 hours of Melbourne, and Ararat, Shepparton, Benalla to within 2 hours.

The effect is more significant for local intra-regional trips, whereby a greater number of outer regional centres are brought to within one hour's travel time of their main regional centres of Geelong, Ballarat, Bendigo, Seymour and Traralgon; the effect is depicted in Figure 5.14.

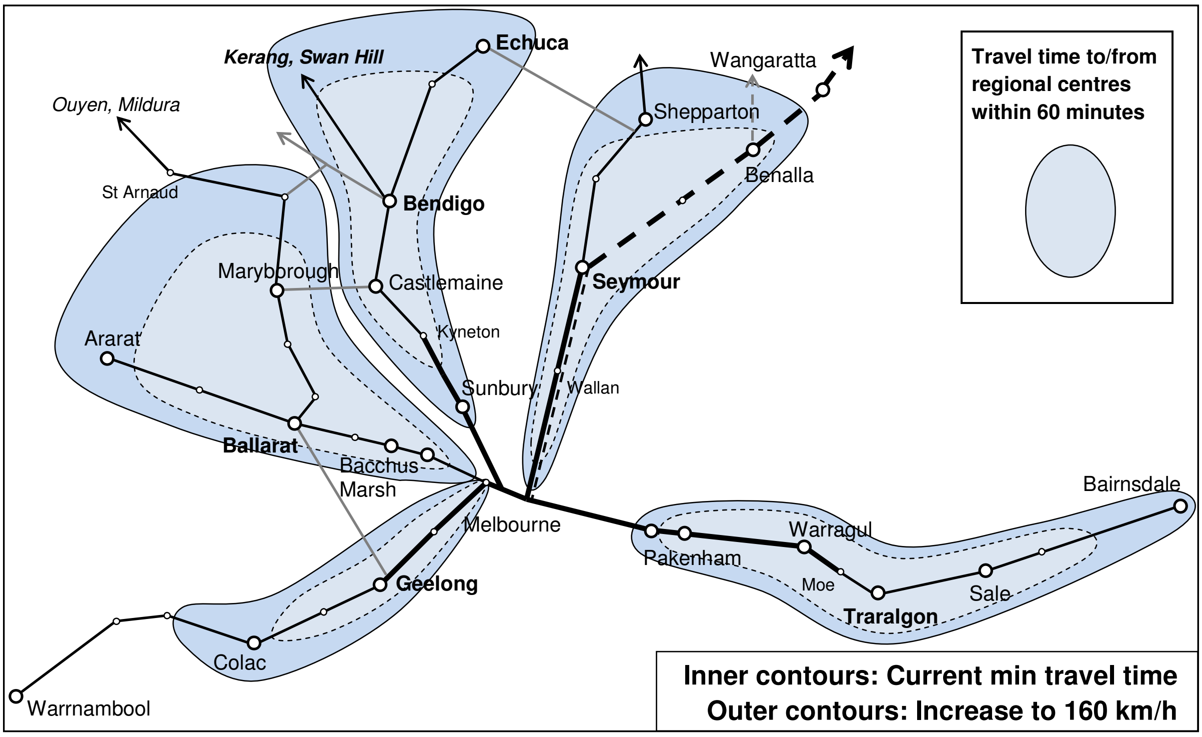


Figure 5.14: Accessibility to/from major regional centres

200 km/h maximum speed on all regional lines

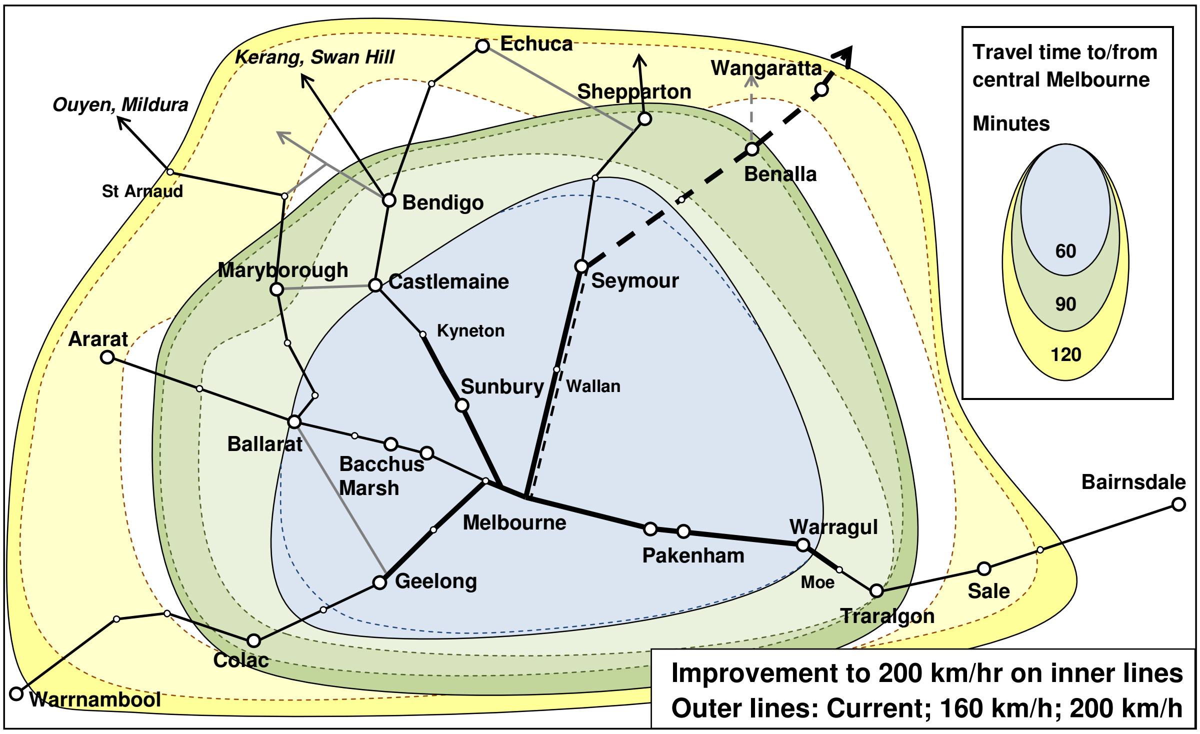


Figure 5.15: Accessibility to/from Melbourne: 200 km/h inner lines, varying outer lines

Upgrading all lines to 200 km/h has a major effect on journeys within one hour's travel time to/from Melbourne. The regional cities of Ballarat, Castlemaine, Seymour and Warragul are brought comfortably to within one hour of Melbourne. The effect is also sizeable for journeys of 1.5-2 hours from Melbourne, whereby there is a large expansion of accessibility into outer regional areas for upgrades to speeds of 160 and 200 km/h on outer lines. The combination of 200 km/h on inner lines and 160 km/h on outer lines brings all major outer regional centres (except for Warrnambool and Bairnsdale) to within 2 hours of Melbourne; an improvement to 200 km/h on outer lines brings only marginal additional gains.

250 km/h maximum speed on all regional lines

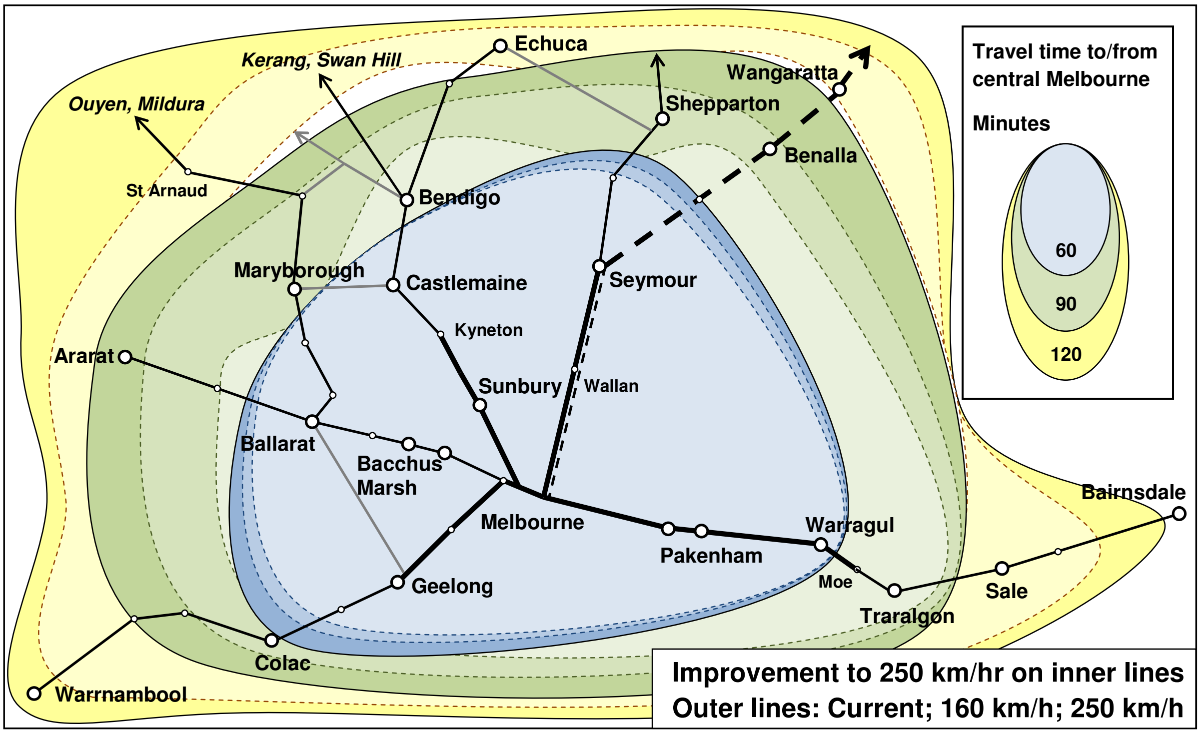


Figure 5.16: Accessibility to/from Melbourne: 250 km/h inner lines, varying outer lines

Upgrading all lines to 250 km/h marginally increases accessibility for trips within one hour of Melbourne; regional centres in this band experience travel time gains and the regional centres of Bendigo and Maryborough are brought closer to but remain outside the one hour band. The effect is again large for journeys of 1.5-2 hours from Melbourne with speeds of 160 and 250 km/h on outer lines. The effect of the increase to 250 km/h on outer lines is more pronounced than for 200 km/h (Ararat is brought to within 1.5 hours of Melbourne and Warrnambool to within 2 hours) but the overall improvement over 160 km/h on outer lines is marginal.

With more extensive infrastructure improvements and capacity enhancement measures that permit a greater number of express services and higher average speeds, it could be possible to upgrade lines to 250 km/h to achieve a greater average/maximum speed factor. An increase to from 0.6 to 0.7 yields an average speed of 175 km/h, which is applicable for fast services.

The effect of upgrading lines to 250 km/h with extraordinary enhancements is depicted in Figure 5.17. In this instance the key regional centre of Bendigo is now within one hour from Melbourne; in addition, the more densely populated Latrobe Valley region between Warragul and Traralgon (centred on Moe) is around one hour from Melbourne. The diagram assumes all lines (inner and outer) are upgraded to this standard and hence outer regional cities are brought within shorter travel times to Melbourne: Colac within one hour, Maryborough and Shepparton just beyond one hour, Echuca and Wangaratta within 1.5 hours, and Bairnsdale, Swan Hill and Wodonga-Albury within 2 hours. A description of the sorts of enhancements required is given in the section 5.4.

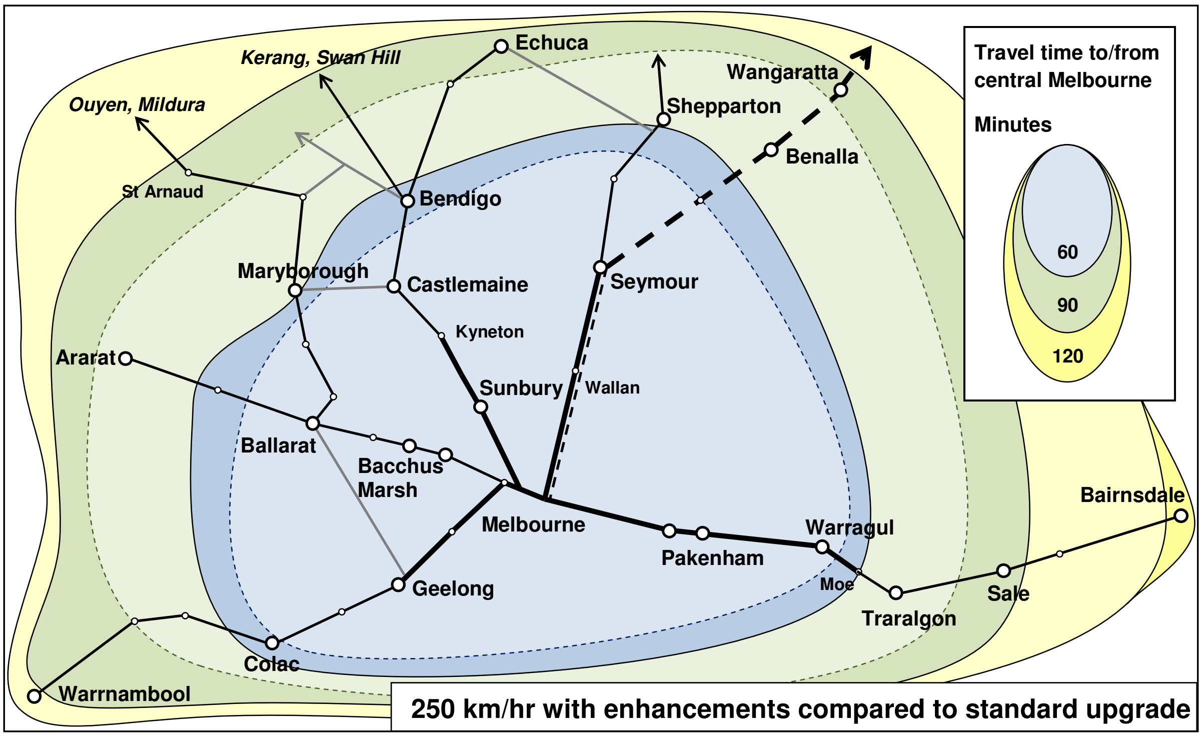


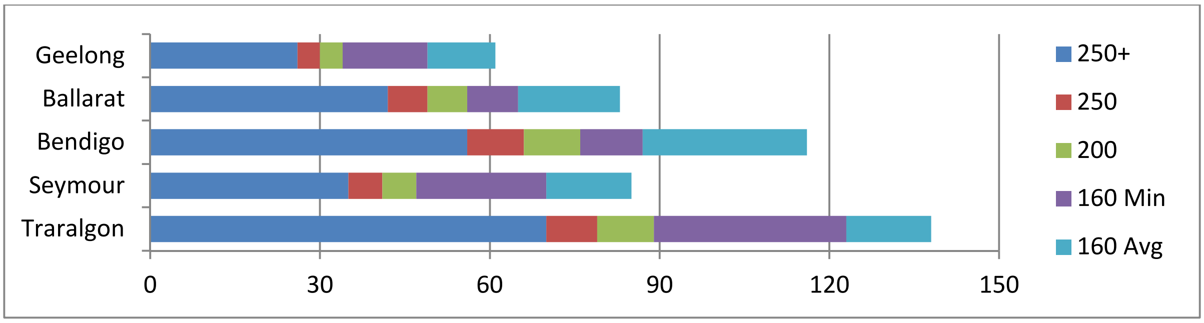
Figure 5.17: Accessibility to/from Melbourne: 250 km/h with enhancements

The above improvement scenarios demonstrate the possibilities for travel time reductions and improved accessibility between Melbourne and the regional centres (and within the regional corridors themselves). Within the current supply (before further line speed enhancements), significant gains in travel time and accessibility are made based on minimum travel time over average travel time. The centres of Ballarat, Seymour and Castlemaine are slightly in excess of one hour from Melbourne and on the borderline of acceptability for commuting; Bendigo is just under 1.5 hours and populated centres on the Traralgon line (from Warragul) are 1.5-2 hours, and beyond what most commuters deem acceptable. If the majority of departures (or at least the most important peak services) could achieve close to current minimum travel times, it would represent a significant improvement in accessibility to cities on the one hour band.

Increasing the speed on inner regional lines to 200-250 km/h brings Ballarat comfortably in and several smaller regional centres to within one hour of Melbourne; the cumulative effect of shorter inner trips shortens trips times to outer regional centres and increases accessibility, bringing several to within the acceptable ‘occasional trip’ time 1.5-2 hours to Melbourne.

Upgrading the outer lines (beyond Geelong, Ballarat, Bendigo, Seymour and Traralgon) to 160 km/h has a substantial positive impact on accessibility to both Melbourne and within the regional corridors for each of the inner line speed scenarios. Naturally, the greater the speed of the inner lines the greater the accessibility of outer regional centres to/from Melbourne; but it is interesting to note that increasing the speed to 200 or 250 km/h offers marginal additional improvement over 160 km/h in terms of the number of regional centres brought to within 1.5-2 hours access to Melbourne.

The analysis demonstrates the trade off between travel time reductions/increased accessibility and cost of supply improvements. Utilising high speeds universally achieves the greatest time reductions and accessibility gains but at heightened cost; combining different speeds, such as 200-250 km/h on inner lines and 160 km/hr on outer lines, may offer a substantial proportion of the gains of the 'all-out' scenario (e.g. much improved accessibility to the more populous inner regional cities and in between centres of a regional corridor) but at significantly reduced cost; further, increasing some lines to 250 km/h with extraordinary enhancements (such as to the Bendigo line which would bring the large regional city of Bendigo to within one hour of Melbourne) could offer significant additional benefits at marginally extra cost. It is beyond the scope of this thesis to conclude which option achieves the most desirable balance between increased accessibility and regional growth on the one hand, and supply improvement costs on the other. The next section, which estimates passenger growth for the different scenarios, and the subsequent section on longer-term regional effects, attempt to provide further insights on appropriate supply improvements.



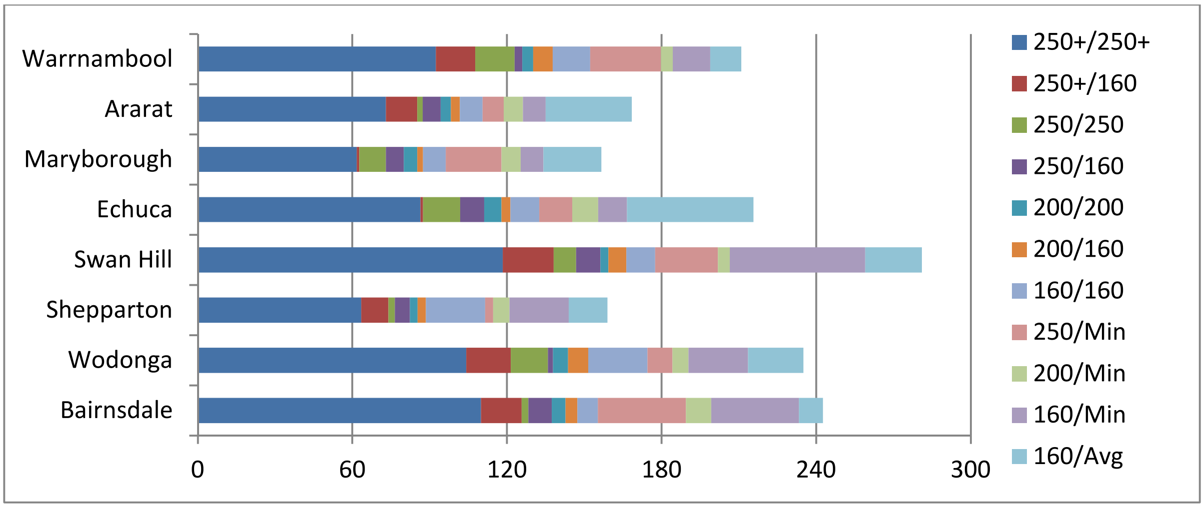


Figure 5.18: Travel time gains based on speed scenarios (inner line/outer line speeds)

5.3.4 Service frequency and supply improvements

Since frequency of service is the next most important factor in the generation of travel after travel time, consideration of it should be given when discussing supply improvements.

Currently, all inner regional-Victoria lines offer a frequency of less than one hour, as do high-speed regional services in the Stockholm-Mälaren region; a frequency of not greater than one hour is thus considered an acceptable minimum for regional high-speed services covering travel times of around one hour and distances of 100-150 kilometres. No further frequency increase is deemed necessary for inner regional services. For outer regional services, which vary in average frequency from 1:46 to 5:46, some improvements are necessary to complement the travel time reductions. In the absence of guidance on appropriate frequencies for longer-distance services covering travel times of 1.5-2+ hours, the following stepped increases are applied in respect of current frequencies: 0% for ≤ 2 hours, 50% for 2-3 hours, and 100% for > 3 hours; increases apply for trips to/from Melbourne and do not preclude additional intra-regional services which should reflect improved accessibility within regional corridors. The effect of the frequency increases is to flatten the variation in frequency between the different lines and achieve an acceptable interval for occasional commuting that is reflective of lower demand and longer travel times/distances presently experienced in the outer regions.

The frequency improvements proposed for outer lines are unlikely to generate a significant rise in work-related commuting (≤ hourly to attract daily commuters) but are rather intended to enable more occasional work-related and leisure travel and to stimulate passenger growth, rendering it feasible to further increase frequencies and ultimately facilitate daily commuting.

A summary of line speeds and frequencies for current services and future scenarios is given in Table 5.6. It shall serve as the basis for passenger growth calculations in the next section.

Table 5.6: Summary of line speeds and frequencies: current and future

<table>
<tr><th>Line / service</th><th colspan="2">Current service</th><th colspan="4">Future scenarios</th></tr>
<tr><td>Inner lines</td><td>Speed</td><td>Freq</td><td colspan="3">Maximum line speed</td><td>Freq</td></tr>
<tr><td>Geelong</td><td>160</td><td>0:37</td><td>160</td><td rowspan="5">200</td><td rowspan="5">250</td><td>0:37</td></tr>
<tr><td>Ballarat</td><td>160</td><td>0:55</td><td>160</td><td>0:55</td></tr>
<tr><td>Bendigo</td><td>160</td><td>0:54</td><td>160</td><td>0:54</td></tr>
<tr><td>Traralgon</td><td>130-160</td><td>0:54</td><td>130-160</td><td>0:54</td></tr>
<tr><td>Seymour</td><td>130</td><td>0:49</td><td>130</td><td>0:49</td></tr>
<tr><td>Outer lines</td><td>Speed</td><td>Freq</td><td colspan="3">Speed combinations</td><td>Freq</td></tr>
<tr><td>Warrnambool</td><td>115</td><td>5:46</td><td rowspan="8">160</td><td rowspan="8">Current
160
200</td><td rowspan="8">Current
160
250</td><td>2:53</td></tr>
<tr><td>Ararat</td><td>130</td><td>1:58</td><td>1:58</td></tr>
<tr><td>Maryborough</td><td>100</td><td>2:40</td><td>2:00</td></tr>
<tr><td>Echuca</td><td>75-80</td><td>1:46</td><td>1:46</td></tr>
<tr><td>Swan Hill</td><td>90</td><td>2:43</td><td>2:02</td></tr>
<tr><td>Bairnsdale</td><td>100</td><td>5:40</td><td>2:50</td></tr>
<tr><td>Shepparton</td><td>100</td><td>2:28</td><td>1:51</td></tr>
<tr><td>Albury-Wodonga</td><td>115</td><td>2:36</td><td>1:57</td></tr>
</table>

5.3.5 Estimated passenger growth by demand elasticities

Passenger growth as a result of transport supply improvements is determined using demand elasticities, which are applied to both travel time gains and frequency increases; the resulting growth factor is a product sum of the two. To account for trips to/from intermediate stations, the growth factors are population-weighted averages of destination and preceding stops. The elasticities used in the 'Green Train' project are applied in these calculations, which are based on the assumption that new travellers come mainly from car (than from plane); since all new rail travellers in Melbourne-regional Victoria will come from car or be newly generated, the elasticities are applicable. The growth factors for the different scenarios are presented in Table 5.7 and a full calculation example (250/160 km/h) is tabulated in Appendix 5. Ticket prices and comfort level are assumed to be unchanged and are not included in the analysis.

Table 5.7: Growth factors by demand elasticities

To/from Melbourne		Maximum line speeds						
Inner line	From/to	160*	200			250 (250+)†		
Geelong	Melbourne	1.18*	1.39			1.46 (1.46)		
Ballarat	Melbourne	1.20*	1.30			1.37 (1.44)		
Bendigo	Melbourne	1.21*	1.29			1.35 (1.40, *2.03*)		
Seymour	Melbourne	1.15*	1.35			1.39 (1.42)		
Traralgon	Melbourne	1.14*	1.37			1.43 (1.49, *1.92*)		
Outer line	From/to	160	Now	160	200	Now	160	250
Warrnambool	Melbourne	1.75	1.51	1.88	1.94	1.55	1.92	2.04
Ararat	Melbourne	1.48	1.38	1.53	1.55	1.44	1.57	1.62
Maryborough	Melbourne	1.64	1.44	1.69	1.71	1.50	1.74	1.78
Echuca	Melbourne	1.58	1.42	1.66	1.67	1.49	1.70	1.74
Swan Hill	Melbourne	1.53	1.33	1.61	1.66	1.36	1.68	1.80
Bairnsdale	Melbourne	1.61	1.71	1.91	1.94	1.80	1.98	2.04
Shepparton	Melbourne	1.56	1.50	1.70	1.72	1.54	1.74	1.79
Albury-Wodonga	Melbourne	1.60	1.58	1.79	1.83	1.63	1.83	1.95

*Based on current upgraded state with maximum speed 160 km/h (130 km/h on Seymour line); factors represent difference between current average time and minimum time on all services.
†(250+) represents upgraded lines to 250 km/h with extraordinary enhancements

To/from regional centres		Max line speed		
Outer line	From/to	160	200	250
Warrnambool	Geelong	1.73	1.79	1.88
Ararat	Ballarat	1.42	1.46	1.52
Maryborough	Ballarat	1.68	1.68	1.68
Echuca	Bendigo	1.50	1.53	1.58
Swan Hill	Bendigo	1.72	1.77	1.84
Bairnsdale	Traralgon	1.60	1.63	1.67
Shepparton	Seymour	1.54	1.58	1.65
Albury-Wodonga	Seymour	1.56	1.62	1.71

Growth factors for inner lines vary between 1.3 and 1.46 for upgrades to higher speeds and between 1.5 and 2.04 for outer lines upgraded in conjunction with inner lines. The results confirm what the accessibility analysis demonstrated: there is a significant growth step for the upgrade of inner lines from current to 200 km/h and from 200 to 250 km/h (although the step is greater from current to 200 km/h); and there is a significantly greater growth step on outer lines from current to 160 km/h than from current to higher speeds (200-250 km/h). For trips between centres within regional corridors, growth factors vary between 1.4 and 1.9 relatively linearly with step increases in speed, although the greatest gain is from the current speed to 160 km/h which suggests a 40-70% growth increase. As previously mentioned, growth factors for longer trips in excess of two hours (outer regional trips to/from Melbourne) may be over-estimated due to sometimes higher than marginal changes and should be noted with caution.

Comparison with Svealand line elasticities

The Svealand line study (Fröidh, 2003) determined considerably higher elasticities of -1.7 to -2.4 for an approximate travelling time of one hour on long-distance regional journeys on the Svealand line. Assuming a roughly even proportion of business and private travellers, a mid-value of -2.0 is appropriate to use. Applying this increased elasticity to journeys experiencing a new travel time of around one hour as a result of improvements generates revised growth factors given in Table 5.8; travel times are listed beside growth factors for reference. Journey times of 'around one hour' are designated greater than 45 minutes and less than 70 minutes. Times outside these limits are crossed out; inner lines with times in these limits are shaded.

Table 5.8: Growth factors by increased elasticity based on Svealand line

Max speed	Current	160* km/h		200 km/h		250 km/h	
Service	Avg time	Time	Growth	Time	Growth	Time	Growth
Geelong	1:01	0:49	1.39	0:34	1.87	0:30	2.02
Colac	2:10	1:29	1.98	1:12	2.32	1:02	2.50
Castlemaine	1:32	1:07	1.54	0:59	1.72	0:51	1.89
Bendigo	1:56	1:27	1.50	1:16	1.69	1:06	1.87
Ballarat	1:23	1:05	1.44	0:56	1.65	0:49	1.83
Maryborough	2:35	1:34	1.84	1:23	2.00	1:12	2.15
Warragul	1:36	1:25	1.24	1:02	1.71	0:56	1.84
Seymour	1:25	1:10	1.35	0:47	1.89	0:41	2.04

The results indicate growth factors of around 1.4-1.5 by reducing all services to the minimum travel time, around 1.7 upgrading to 200 km/h and around 1.85-2.0 upgrading to 250 km/h, an almost two-fold increase. All of the above services (except for Colac and Maryborough) are located on inner regional lines and thus the frequencies are unchanged from current. Italicised values for Bendigo (2.03) and Traralgon (1.92) in the (250+) case in Table 5.7 represent trips achieved in around one hour (for which the higher elasticity applies) based on the upgrade of these lines to 250 km/h with extraordinary enhancements.

At this point, it is useful to compare the projected growth factors with the Svealand line case for similar travel time reductions. Table 5.9 summarises the improved supply and trip growth between Stockholm and Eskilstuna in the years following the high-speed line's introduction.

Table 5.9: Regional travel on SJ between Eskilstuna and Stockholm
Source: Repeated Table 4.4 (Fröidh, 2003)

Period	No. services Mon-Fri each direction	Travelling time (hrs:mins)	Fare, single, 2nd class (SEK, 2003)	No. journeys (000's/yr)	Incr. factor
Up to spring 1993	8 trains	1:40	115	230	1
Autumn 1993 - spring 1997	18 buses	1:55-2:20	105-120	440	2
Summer 1997	17 HS trains	1:00	55	1400	6
Autumn 1997	17 HS trains	1:00	110	1200	5
2001	18 HS trains	1:02	113-135	1600	7

The replacement of trains with buses of similar (but slightly greater) travel time but twice the frequency from 1993 to 1997 resulted in a growth factor of 2. The reintroduction of trains in 1997 at around half the travel time (to one hour) and similar frequency and price resulted in a growth factor of 5. This represents an approximate overall growth factor of 2.5 between 1993 and 1997 that can be attributed to the reduction in travel time from 1:40-2:00 to 1 hour. The increase from 1997 to 2001 is attributed to longer-term regional development effects. Similar time reductions to around one hour on regional Victoria lines (indicated by grey highlight) yield growth factors of 1.8-2.5, or approximately 2 overall, which is 33% lower than for the Svealand line. This suggests that the growth factors calculated using the higher elasticity may be more realistic (and possibly conservative) for such journeys. The comparison between the two regions suggests that the estimated growth factors for Melbourne-regional Victoria lines are reasonable, though possibly underestimated, and that the higher 'Svealand line' elasticity is applicable to journeys reduced from 1.5-2 hours to 1 hour.

In summary, passenger growth factors of 1.3-2 for inner lines and 1.5-2 for outer lines can be assumed depending on the level (and combination) of line upgrades, although they are based on conservative assumptions; the actual growth rates may be considerably higher, especially for trips reduced to around one hour when daily commuting becomes possible. It is important to note that the growth rates estimated are short-term increases and do not account for longer term effects, which are only possible to measure based on observation over several years after the supply improvements; they represent the dynamic effects of population movements and firm relocations, which occur under certain circumstances, as formerly less-accessible regions become more accessible and attract new residents and businesses; a study of the Stockholm-Mälaren region suggests this leads to more commuting (and increased growth), although the longer-term dynamic effects are addressed in section 5.5 of the thesis.

A non-regional effect that could be considered dynamic (and which is applicable here) is that the increasing travel demand makes it feasible to increase the frequency, which in turn further increases the demand: the so called "Mohring effect".

5.4 Required infrastructure improvements for high-speed

To deliver significantly reduced journey times requires network improvements that permit higher speeds and provide the necessary capacity for services to operate at these speeds at the desired frequency. In proposing infrastructure improvements it is logical to continue with the categorisation of lines as 'inner' and 'outer' in accordance with the speed scenarios analysed in the previous section. It also reflects the different duty and capacity requirements of each type: 'inner' lines have higher capacity and speed requirements, due to higher traffic demands and service frequencies, than 'outer' lines which have less onerous requirements. A summary of the future upgraded line speed/frequency scenarios is given in Table 5.10.

Table 5.10: Summary of upgraded line scenarios

Line category	Max line speeds (km/h)			Frequency
Inner lines	160*	200	250	Less than 1 hour
Outer lines	Current 160	Current 160 200	Current 160 250	2-3 hours
*All inner lines to 160 km/h and achieving current minimum times				

The scenarios approach with different combinations of inner and outer line speeds was useful for analysing the effects on overall journey times and accessibility. In this exercise, inner and outer lines are treated independently, and target speeds are grouped according to the extent of infrastructure enhancements required. The general infrastructure and vehicle requirements for different target speeds are described in Table 5.11.

Table 5.11: Infrastructure and vehicle requirements

Speed	Track	Signalling / control	Vehicles	Electrification
160	Double track (inner lines)	Current signals, TPWS	Current diesel	No
200	Double track; upgrades to sections of existing track	Existing with upgrades	200 kph diesel	No
		New signalling, ATP	Electric, cab sig.	25kV AC
250	Major upgrades to large sections of track	New signalling, ATP	Electric, cab sig.	25kV AC
250+	Substantial track rebuilding	New signalling, ATP	Electric, cab sig.	25kV AC

5.4.1 Upgrades to 160 km/h

Inner lines

Currently, three of the five inner lines are capable of 160 km/h operation outside Melbourne: Geelong, Ballarat and Bendigo; the Traralgon line permits 160 km/h between Pakenham and Traralgon but is limited to 130 km/h on the north track; the Seymour line permits 130 km/h. To permit 160 km/h operation in both directions at all times, so that at least current minimum travel times are achieved, requires duplication to double track (where it is single track) and track upgrades to 160 km/h operation on lower permitted speed sections. Additional passing loops may be required at stations and other locations to permit the passing of express trains.

Table 5.12: Inner line enhancements to 160 km/h, applicable to 200 km/h

Line	Description of required improvements
Geelong	No critical improvements foreseen; assumes completion of 'Regional Rail Link'
Ballarat	Duplication to double track between Deer Park West and Ballarat; the addition of passing loops at stations to permit passing of express trains
Bendigo	Duplication to double track between Kyneton and Bendigo; the addition of passing loops at stations to permit passing of express trains
Seymour	Upgrade to 160 km/h between Craigieburn and Seymour
Traralgon	Upgrade to 160 km/h on North track between Pakenham and Traralgon; duplication to double track between Moe and Traralgon; *Capacity improvement measures (less stopping services, passing sections) between Melbourne and Pakenham to permit higher average speeds (to 80 km/h)

Outer lines

Outer regional lines typically permit speeds of between 100 and 115 km/h and occasionally to 130 km/h (Ararat line) or lower that 100 km/h (Echuca line) on single track line. An increase in the permitted speed to 160 km/h (but retaining single track) requires upgrades to sections of track that are substandard (in terms of track geometry and support) and possible rebuilding of sections of line to satisfy more onerous geometric requirements. More ambitious upgrades to 200 or 250 km/h require extensive track upgrades and rebuilding.

5.4.2 Upgrades to 200 km/h

200 km/h operation is considered the borderline between marginal improvements to current 160 km/h compliant line and significant upgrades with new signalling systems and vehicles. As 200 km/h operation with diesel vehicles with optical signalling is widespread in the UK, it is fair to assume that relatively minor upgrades to signalling and automatic train protection (ATP) would be needed to raise the permitted line speed to 200 km/h; diesel vehicles capable of 200 km/h operation would be required assuming upgrades to the current fleet isn't feasible.

A second option is to electrify the lines: since diesel propulsion can't deliver the same power as electric at higher speeds, there is a run time difference; electrification (of line and vehicles) would therefore offer the benefit of shorter travel times. Track upgrades to 200 km/h assume the same enhancements described in Table 5.12 for 160 km/h (incl. double track) but to more onerous requirements of the higher speed.

5.4.3 Upgrades to 250 km/h (applicable to 200 km/h electrified)

250 km/h operation represents is a significant step from 'fast' trains operating 160-200 km/h. Not only are track quality requirements higher, but 250 km/h operation requires electrification of the line (as diesel trains aren't capable of speeds in excess of 200 km/h), special signalling systems (and ATP) capable of true 'high speed' and high-speed electric vehicles. Also, where part of the line is shared with (electrified) commuter trains, vehicles must be equipped with duel electric and signalling systems for both suburban and high-speed line sections. Upgrades assume the completion of double track on inner lines.

There are two general groupings of upgrades that could be undertaken to achieve 250 km/h operation. The first (described in Table 5.13) assumes continued use of prevailing 1600mm broad track gauge on all lines, high-speed electrification, signalling and vehicles on all lines, with exceptions for the Seymour and Traralgon lines which share a significant portion of their lines with the suburban commuter rail system. The second (described in Table 5.14) includes the provision for conversion to 1435mm standard track gauge, which might offer advantages in the future for integration with interstate (especially freight) lines, although migration to the standard track gauge is not a critical question for a high-speed solution. A brief discussion of the required line/technology upgrades and line specific requirements is given hereunder.

Track upgrades and gauge

As already mentioned, for existing track to accommodate 250 km/h operation would require major upgrades to (and partial rebuilding of) large sections of track to meet the more onerous geometric and support requirements; structures (bridges and tunnels) would also be required. the extent of upgrade depends on current track state and geometry. The 250+ state (250 km/h with extraordinary improvements) requires additional track rebuilding and structures, possible bypasses around stations, and passing loops in order to maintain a higher average speed.

The retention of 1600mm broad track gauge is assumed in the first grouping of line upgrades; retaining broad gauge maintains compatibility with the outer lines, allowing the same vehicles to run the entire route on outer lines to/from Melbourne. Migration to the 1435mm standard gauge would render the lines incompatible with outer lines (assuming they are not converted), requiring separate vehicles on inner and outer lines and forcing a change at inner line termini; a way around this obstacle could be to install 3-rail duel gauge track (1600 + 1435mm) on the inner lines. Incompatibilities in speed, signalling and traction might also force a separation.

Signalling and communications

250 km/h operation requires modern state of the art signalling system to be installed trackside and in vehicles (cab signalling). ERTMS (European Rail Traffic Management System) is the internationally preferred system for new high-speed lines and the target system for the trans-European rail network (UIC, 2012) and is the obvious choice for a new high-speed signalling system. It is also capable of incorporating prevailing train protection systems in its vehicles via a special transmission module (STM), enabling operation on non-ERTMS lines.

Electrification

Above 200 km/h requires line electrification, since diesel-powered vehicles are uneconomic to power speeds in excess of 200 km/h. The internationally preferred system is the 25kV AC/ 50 Hz single-phase system, which is the most efficient in terms of infrastructure and energy and is the target system in Europe (UIC, 2012). As the national grid frequency in Australia is also 50 Hz, it is the most applicable system for new high-speed rail lines. Vehicles operating on two electric power systems (25kV AC and 1500V DC which would be the case for shared lines) requires special power conversion equipment to switch between the two systems, as is common on cross-border trains in Europe.

Table 5.13: First level line upgrades

Line	Track gauge	Signalling	Vehicle requirement	Line electrification
Geelong	1600	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Ballarat	1600	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Bendigo	1600	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Seymour	1600	Cab signalling / ATP and TPWS	Duel electric 25kV AC and 1500V DC	25kV, 50 Hz AC
Traralgon	1600	Cab signalling / ATP and TPWS	Duel electric 25kV AC and 1500V DC	25kV, 50 Hz AC

Table 5.14: Second level line upgrades

Line	Track gauge	Signalling	Vehicle requirement	Line electrification
Geelong	1600 / 1435	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Ballarat	1600 / 1435	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Bendigo	1600 / 1435	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Seymour	1600 / 1435	Cab signalling / ATP	Electric 25kV AC	25kV, 50 Hz AC
Traralgon	1600	Cab signalling / ATP and TPWS	Duel electric 25kV AC and 1500V DC	25kV, 50 Hz AC

Geelong, Ballarat and Bendigo lines – Regional Rail Link

Regional Rail Link is a new dedicated regional rail line running from West Werribee through Deer Park, Sunshine and Footscray to Melbourne Southern Cross Station. It separates regional trains from metropolitan trains, giving Geelong, Bendigo and Ballarat line trains their own dedicated tracks through the metropolitan system from Sunshine to Southern Cross Station. (Regional Rail Link, 2012) The new line is depicted in Figure 5.19. The rail link enables the Geelong, Bendigo and Ballarat lines to be treated as a group when proposing line upgrades to higher speeds, since the line is for their exclusive use and may be modified without disrupting metropolitan services. The first and second level upgrades are identical except for the second including the provision for conversion to 1435mm standard gauge.

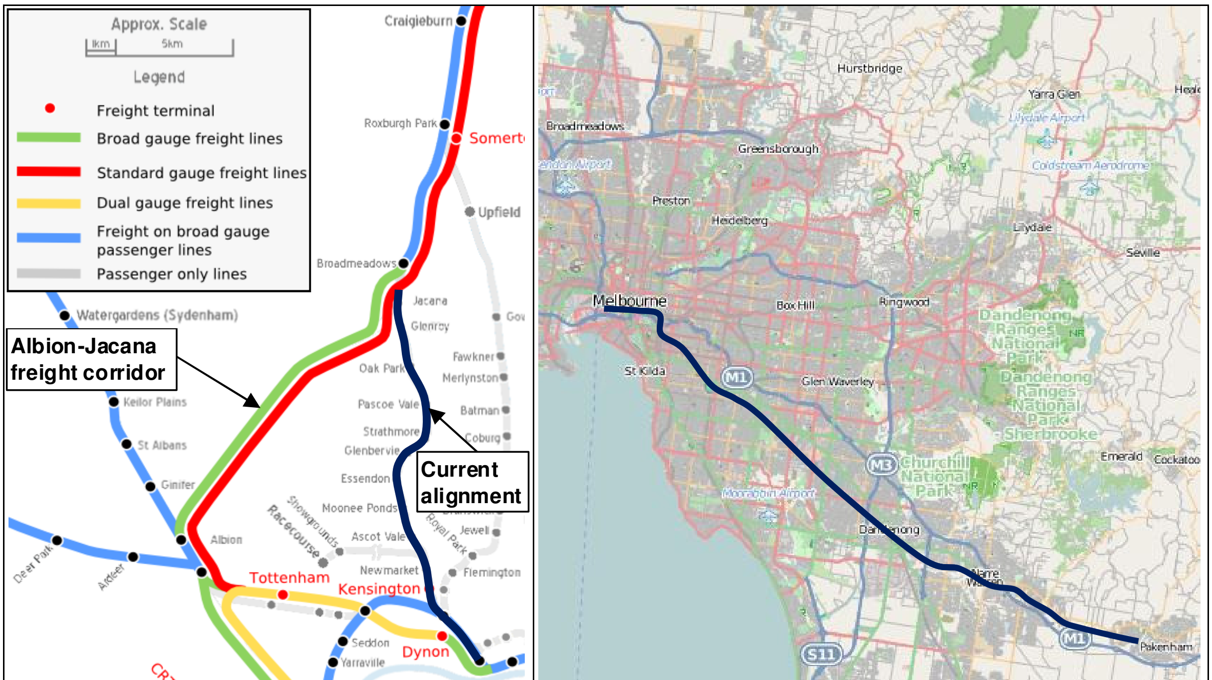
Figure 5.19: Regional Rail Link / Proposed interstate high-speed rail corridors (right)
Source: http://www.regionalraillink.vic.gov.au/home / AECOM Aust. (2011)

Seymour line

In the first upgrade level, the Seymour line uses the current alignment, sharing suburban commuter line between Melbourne and Craigieburn and then upgraded 1600mm double track high-speed line to Seymour. The use of both suburban and high-speed lines requires vehicles with duel power systems (1500V DC on suburban line and 25kV AC on high-speed line) and both suburban train protection system and high-speed cab signalling (e.g. ERTMS).

In the second upgrade level, the line uses the Albion–Jacana freight corridor with 1600mm or 1435mm high-speed double track between Melbourne and Craigieburn, and continuing on to Seymour. The Albion–Jacana railway corridor currently consists of single broad gauge and standard gauge (for interstate traffic) tracks; depending on the adopted gauge for high-speed, either the broad gauge track could be converted to standard gauge (resulting in an exclusively standard gauge line) or an additional track added to retain both track gauges. The proposal is depicted in Figure 5.20 (left).

Upgrade of the Seymour line to high-speed should be considered in view of plans for inter-state high-speed rail (between Melbourne-Canberra-Sydney-Brisbane) that propose corridors aligning with the current Seymour line/North-East standard gauge line corridor, as depicted in Figure 5.19 (right). All alignments pass via Seymour and then divide with some alignments continuing via Shepparton and others via Benalla-Wangaratta. If the line is built, it would be possible to operate regional high-speed services on the interstate line, a scenario described by the second upgrade level. It would also enable integration of regional high-speed with inter-state high-speed services, permitting interstate travel from regional areas.



Seymour line: Melbourne-Craigieburn Source: overlay on Wikipedia (2012)	Traralgon line: Melbourne-Pakenham (suburban part) Source: overlay on map from OpenStreetMap (2012)

Figure 5.20: Seymour line alignments / Traralgon line (suburban section)

Traralgon line

Both upgrade levels are identical for the Traralgon line, since there is no practical possibility to have exclusive high-speed line over the entirely of the line; it traverses 30 km of suburban line shared with commuter trains (depicted on a map in Figure 5.20, right) over which there is insufficient space to add dedicated high-speed track. A new high-speed line would commence from Pakenham or closer to Melbourne where space permits. The line would require vehicles with duel power systems (1500V DC on suburban line and 25kV AC on high-speed line) and duel suburban train protection system and high-speed cab signalling (ERTMS); track gauge is exclusively 1600mm. All high-speed proposals assume an increase in average speed from 60 to 80 km/h through the suburban zone via capacity enhancements and less frequent stopping; quadrupling the track in the suburban zone between Caulfield and Dandenong (or Pakenham) is another option that would improve capacity and deliver significantly shorter run times.

Implications for outer lines

Given their extensive length and lower traffic usage than the inner lines, it may be difficult to justify the high investments required for high-speed rail on the outer lines in the early stages of its development. Electrification, new signalling and possible conversion to standard gauge might be prohibitively expensive, but relatively modest track improvements permitting higher speeds (to 160 km/h or greater) would offer significant benefits at much reduced cost. Thus a feasible network model is the upgrade of inner lines to 200-250 km/h and outer lines to 160 km/h (or greater depending on the marginal cost of speed increases and vehicle capabilities).

5.4.4 Network speed maps and alignments

First and second level line upgrades to 200/250 km/h on inner lines (and to 160 km/h on outer lines) are depicted schematically in Figure 5.21 and Figure 5.22 respectively.

Approximate base alignments for upgraded inner (200/250 km/h) and outer (160 km/h) lines have been constructed based on existing line alignments. Figure 5.23 depicts upgraded inner lines which allow for some smoothing of curves and straightened sections; Figure 5.24 depicts the outer lines, which follow existing alignments exactly, and show some possible future line extensions, including a peripheral line running Geelong-Ballarat-Castlemaine-Seymour and restored lines to Mildura and Leongatha; future western extensions need not be precluded.

Tilting trains for higher speeds on difficult geometry

Tilting trains offer the possibility to achieve higher speeds and shorter travel times on lines with difficult geometry (i.e. lines with many curves) at marginal extra investment over non-tilt trains. The ‘Green Train’ project’s proposal is trains for speeds 250 km/h (or higher) equipped with car-body tilt on conventional electrified line. It is mainly intended for old line not built for current commercially desirable travel times (Fröidh, 2012). It could be an option to use on older ‘outer’ lines when more expensive track upgrades aren’t economically viable. The track must however be able to cope with higher speeds in curves, requiring possible upgrades.

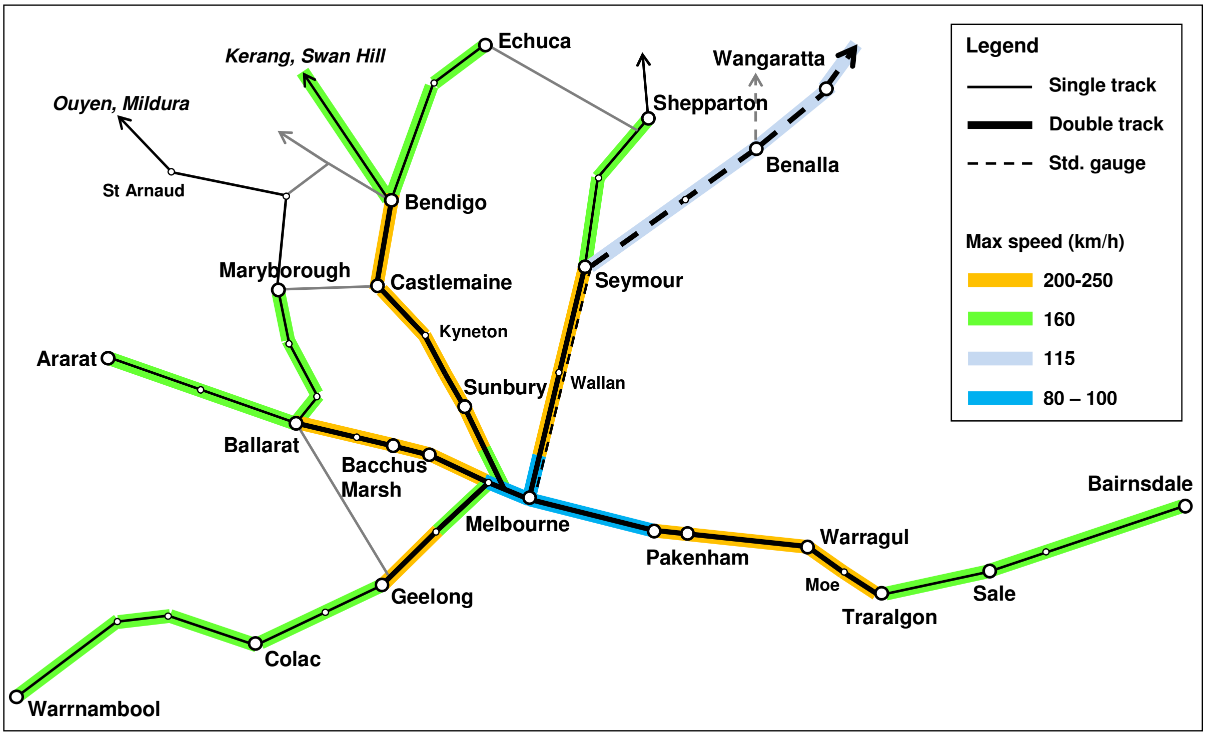


Figure 5.21: First level line upgrades

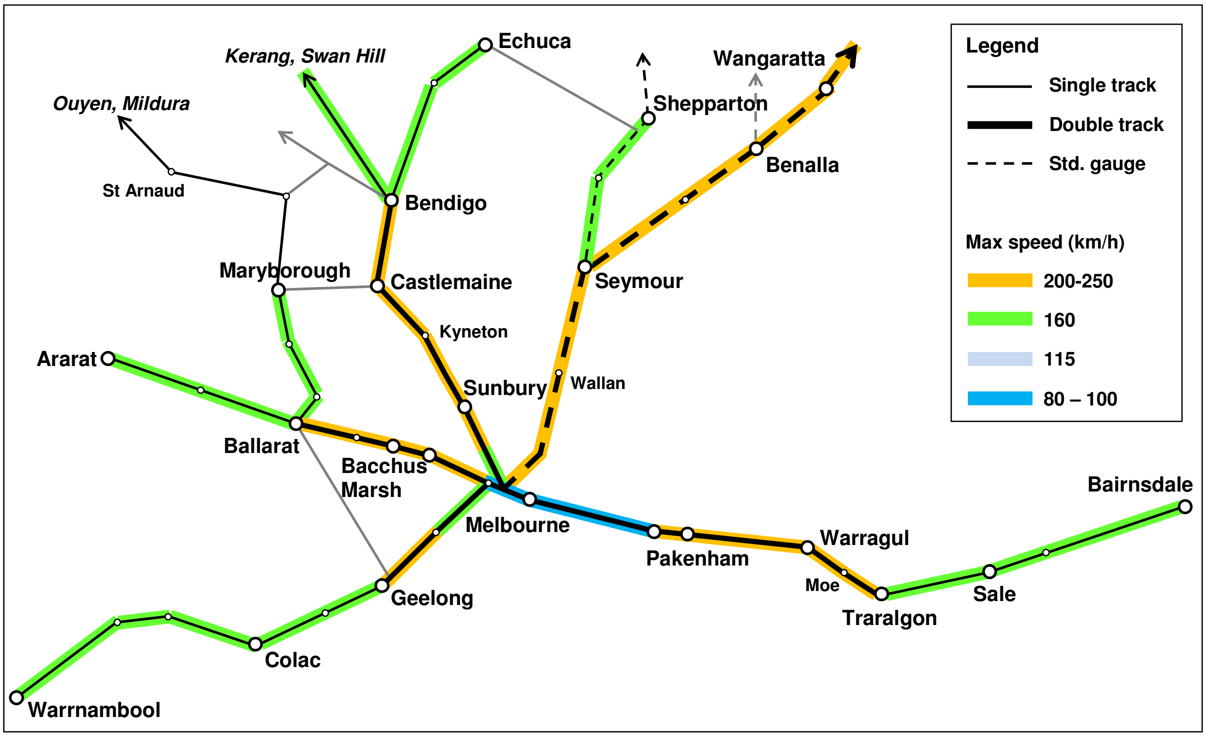


Figure 5.22: Second level line upgrades

Note: Assumes construction of interstate high-speed line along Seymour-Albury corridor

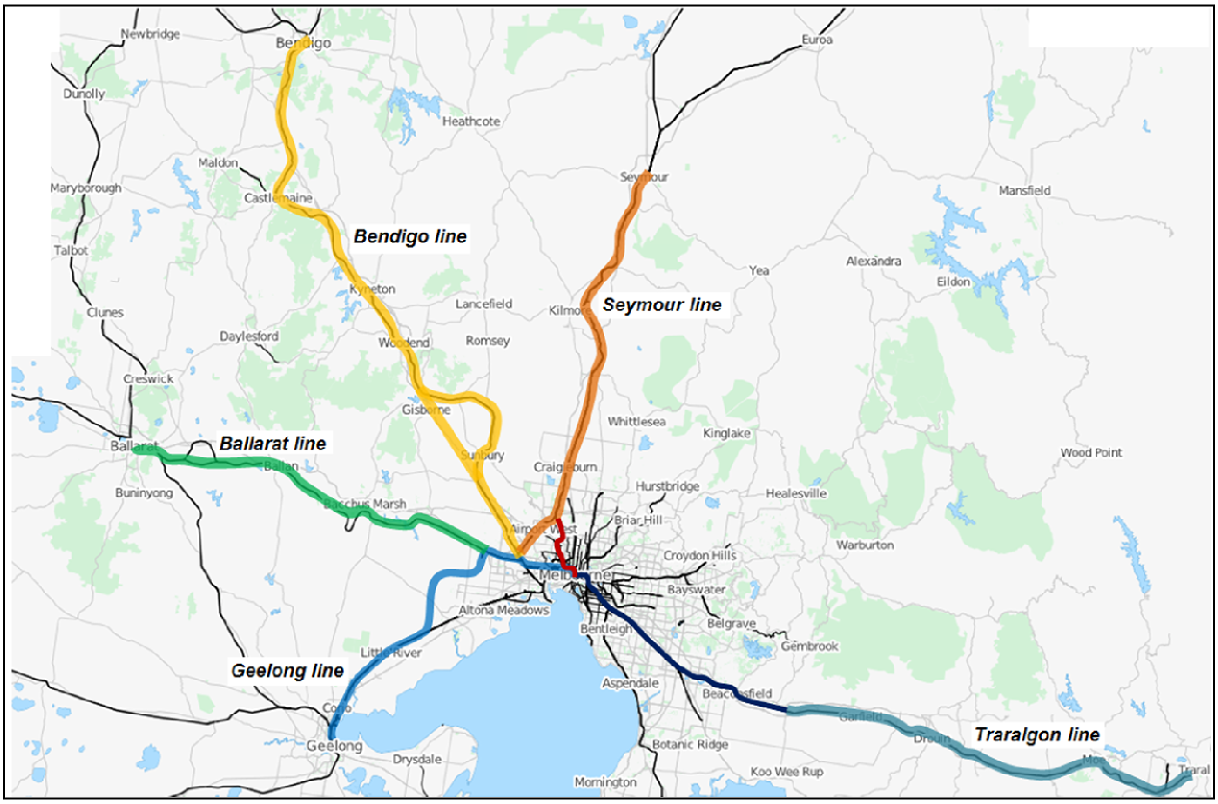


Figure 5.23: Inner line alignments for 200/250 km/h high-speed operation
Source: overlays on maps from OpenStreetMap (2012)

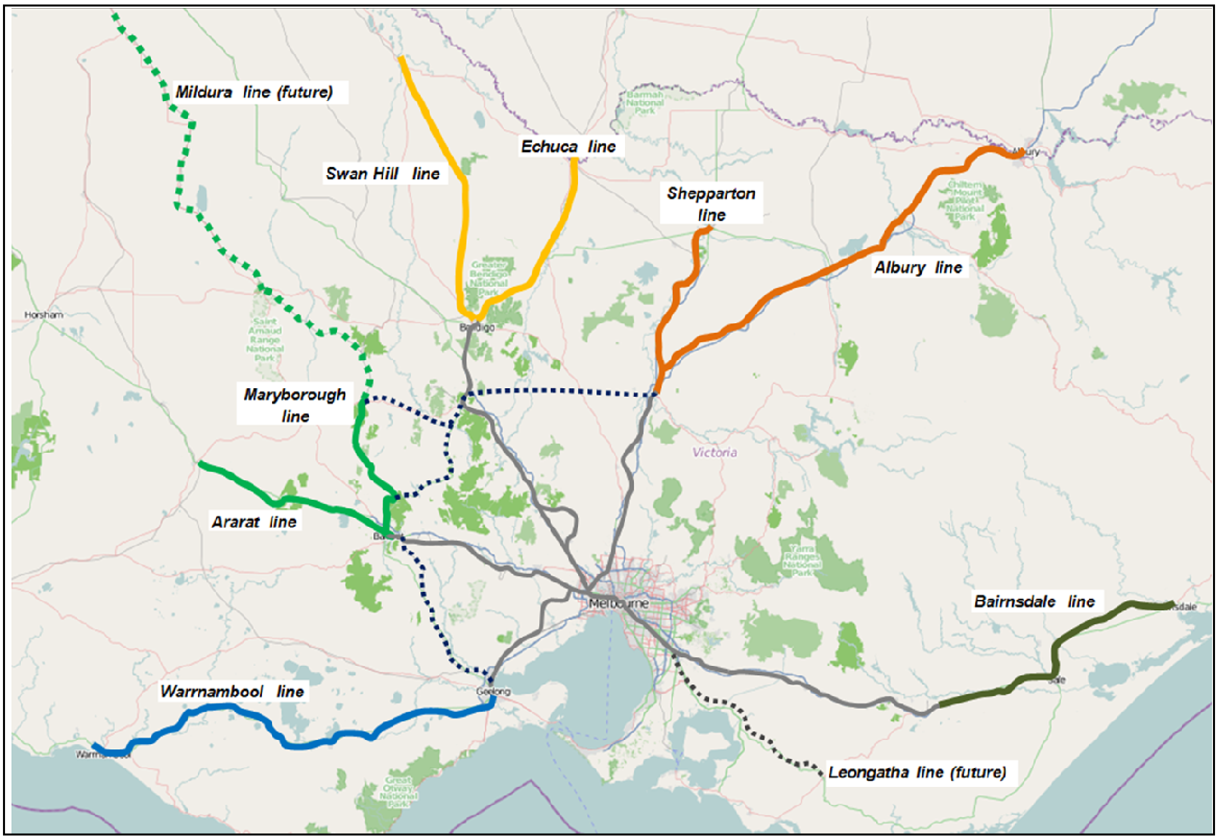


Figure 5.24: Outer line alignments for 160 km/h operation (incl. possible extensions)

5.5 Long-term impacts on regional development

Section 5.3 studied the short-term effects of supply improvements on the Melbourne-regional Victoria rail network. Reduced travel times (through the introduction of higher speeds) and higher frequencies increase accessibility between regional centres, which enables commuting where it was formerly time-prohibitive and increases the attractiveness of rail over road for work and private trips, travel patterns that are reflected in a relatively static and instantaneous increased passenger growth. The longer-term effects are dynamic, since they are related to locational changes in population and employment, and are thus difficult to predict and rely on observation over a long period of time; even then it is difficult to isolate the effects of rail. To theorise on the longer-term regional effects, experience from the Stockholm-Mälaren region is applied to Melbourne-regional Victoria through a comparative city-twinning approach, as are concepts from the literature.

5.5.1 Regional effects based on Stockholm-Mälaren Region

The brief study into the emerging longer-term effects in the Stockholm-Mälaren region serves as a useful basis for comparison to Melbourne-regional Victoria. The regions are comparable in terms of geographic scale and economic activity, despite the Stockholm-Mälaren region exhibiting a more polycentric structure and Melbourne-regional Victoria a monocentric one dominated by the capital. Economically, both regions possess an emerging services sector but the traditional sectors are more distinct in nature and location: the Mälaren Valley is oriented more around manufacturing, which is spread around the region but almost non-existent in the services-oriented capital Stockholm; regional Victoria is based around primary industries and some services, while the bulk of manufacturing is in Melbourne and Geelong. The balance of industry in each region isn't as important as the presence of a services and knowledge-based sector, as the latter offers greater potential for high-speed rail than the traditional industries, which may simply be grouped together to simplify the comparative analysis. It is assumed that the level of services sector activity is proportional to the population of each city region.

A study of the longer-term commuting, population and employment patterns in Stockholm-Mälaren region found that rail supply improvements appear to have had a positive and lasting effect on population and job growth in the regions. Steadily increasing outward commuting signalled the settlement of new residents, who chose to move to smaller regional centres for economic and welfare reasons in exchange for (possibly longer and costlier) commuting to work; inward commuting signalled an increase in local economic activity, as firms relocating to the region were served by workers commuting in from outside. The (universally positive) commuting patterns were accompanied by positive growth in population and jobs in almost all cases; a few smaller and more isolated centres reported marginally negative population and jobs growth which was matched by lower than average levels of inward commuting. The negative growth however appeared to have occurred in earlier years before/during upgrades and showed signs of recovery in subsequent years, evidence of the possible delayed impact of rail improvements on regional development.

5.5.2 Comparison by city pairing

The pairing of towns and cities with a similar population size, character and distance from the capital in each region enables a more rigorous assessment of the expected regional effects on centres with different characteristics. The basis for city pairs is primarily population size and road distance from the capital, but also proximity to other towns/cities and transport links and scale of the local economy. In the absence of detailed information and data on labour markets in Melbourne-regional Victoria, the presence (or not) of a local economy and population size shall be taken as the measure of the extent of the local labour market. A survey of cities and towns in the two regions identified several pairs listed in Table 5.15; an extract of the longer-term changes in the Stockholm-Mälaren region (from Table 4.10) is given in Table 5.16.

Table 5.15: City pairs: Melbourne-regional Victoria, Stockholm-Mälaren region

Melbourne-regional Victoria			Stockholm-Mälaren region		
City/town	Road dist Melbourne	City Population	City/town	Road dist Stockholm	City Population
Gisborne	53	6,398	Nykvarn	49	6,497
Kilmore	73	4,721	Läggesta	65	3,726
Geelong	75	160,991	Uppsala	72	140,454
Ballarat	115	78,221	Västerås	110	110,877
			Eskilstuna	112	64,679
Castlemaine	121	7,248	Kungsör	135	5,452
Moe	135	15,582	Köping	147	17,743
Bendigo	151	81,939	Norrköping	162	87,247
Morwell	149	13,399	Arboga	151	10,330
Shepparton	189	50,373	Gävle	175	71,033
Benalla	211	9,129	Hallsberg	224	7,122

Table 5.16: Change in population, jobs, commuting, 1995-2010 Stockholm-Mälaren region

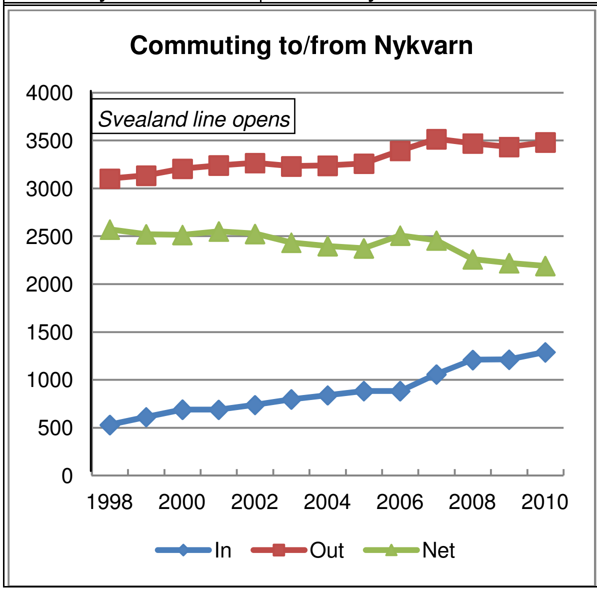
Municipality	Av travel time to Stockholm	Year 2010		Percentage change, 1995-2010 (%)				
						Commuting		
		Population	Job-pop ratio	Popu-lation	Jobs	Inward	Outward	Job-pop ratio
Nykvarn	0:30	9,331	53.9	15.9	46.1	87.0	8.6	12.8
Uppsala	0:39	197,787	95.9	7.8	22.1	76.8	38.1	3.0
Västerås	1:00	137,207	104.3	10.9	14.1	41.6	83.7	-2.3
Eskilstuna	1:06	96,311	98.0	7.7	13.8	66.5	93.9	-2.2
Kungsör	1:28	8,089	76.2	-3.3	11. 4	67.0	8.5	7.1
Köping	1:11	24,905	100.1	-4.7	-6.7	8.8	53.7	-7.2
Norrköping	1:20	130,050	100.8	5.1	7.0	36.8	123.9	-6.0
Arboga	1:22	13,285	92.8	-8.7	-16.5	14.8	50.9	-8.7
Gävle	1:28	95,055	103.1	4.9	8.0	57.2	77.1	-0.4
Hallsberg	1:35	15,275	102.4	-6.8	-1.4	23.3	11.6	4.2

Table 5.16 provides a representative picture of the sorts of longer-term trends than might be expected in the corresponding Melbourne-regional Victoria cities and towns with rail supply improvements. Commuting patterns are the most reliable indicators, and population and jobs growth should be read in conjunction with them: an increase in inward commuting matched by an increase in jobs and/or an increase in outward commuting matched by an increase in population is a fairly solid indicator of settlement changes due to improved rail supply. Other factors (which may or may not be linked to transport supply changes) can influence changes in population and jobs.

To gain a more robust indication of regional effects, a detailed study of a limited number of city pairs is required. Four city pairs of varying population size and distance from the capital shall be chosen, compared and the regional effects examined. In addition to population size and distance from the capital, travel times should be similar for the Mälaren Valley city with existing high-speed service and the regional Victoria city with an improved service.

Gisborne-Nykvarn

City	Nykvarn	Gisborne
Population (city)	6,497 (municipality 9,331)	7,248
Dist from capital	49	53
Current travel time	0:30	Average 0:53; minimum 0:46
New travel time		0:26 - 0:31
Economic sectors	Services, logistics, commuting	Commuting
Transport access	Svealand line, adjacent to E20 road	Bendigo line, adjacent to M79 road
Railway station	Centrally located	On city edge, limited surrounding dev't



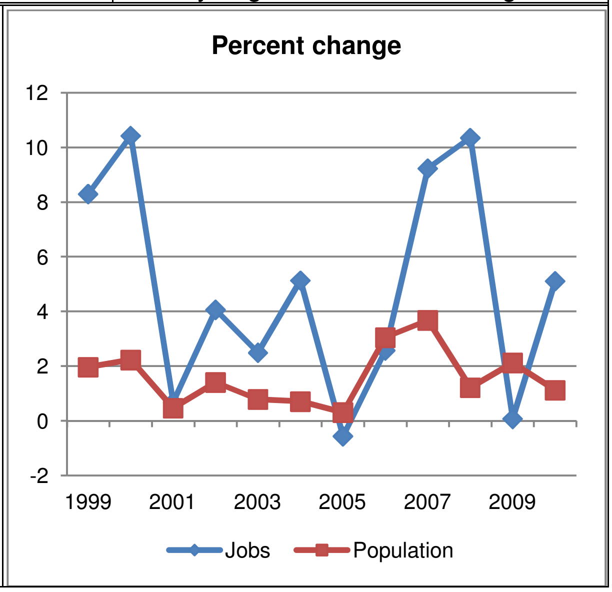


Figure 5.25: Gisborne-Nykvarn city pair summary (Source: SCB, 2012)

Nykvarn and Gisborne are both a short distance beyond the reaches of the metropolitan areas of their capitals and are commuter cities with a local services base (although Nykvarn is more highly developed than Gisborne). Nykvarn has experienced steadily growing in commuting (including a substantial increase in outward commuting to Stockholm) and consistently high population and job growth since the introduction of high-speed in 1997.

Given the close similarity between the two cities, Gisborne could expect similar growth rates in commuting and population growth. Since Gisborne is almost exclusively a commuter city with a limited local economic base, it will experience significantly more outward than inward commuting in the short-medium term, matched by steady population growth. In the longer term, it may become an attractive location for businesses to relocate to due to lower costs and an accessible labour market, thus generating job growth and increased inward commuting.

Ballarat-Västerås

City	Västerås	Ballarat
Population (city)	110,877 (municipality 137,207)	78,221
Dist from capital	110	115
Current travel time	Average 1:00; minimum 0:50	Average 1:23; minimum 1:05
New travel time		0:49-0:56
Economic sectors	Railway industries, electronics, industrial automation, IT, logistics	Services, communications, IT, food and rail industries, agriculture, mining
Transport access	Mälaren line, adjacent to E18 road	Ballarat line, adjacent to M8 freeway
Railway station	Central-south; redevelopment area	Centrally located

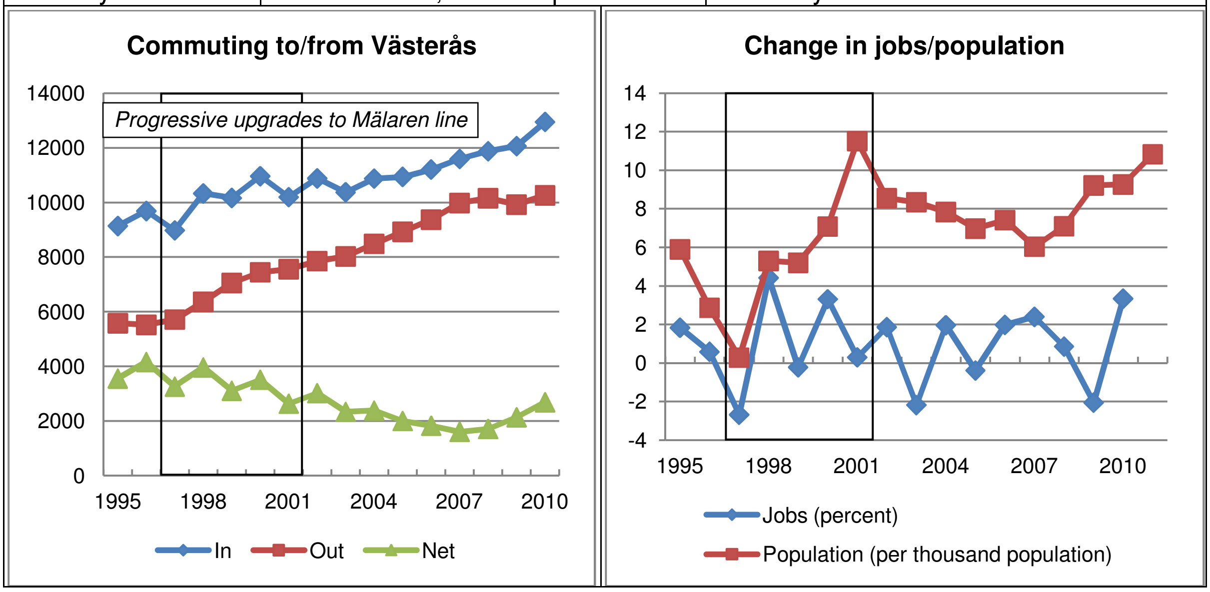


Figure 5.26: Ballarat-Västerås city pair summary (Source: SCB, 2012)

Given its population size and distance from the capital, Ballarat might be paired with either Västerås or Eskilstuna; its population lies in between and all three cities are major centres in their respective regional corridors. Västerås was chosen as its extensive and diverse economic base is considered more similar to that of Ballarat than is Eskilstuna, which has a larger share of commuting; whether Västerås or Eskilstuna was selected as the pair city is inconsequential since both cities achieved similar high levels of growth in commuting, population and jobs in the period 1995-2010; nonetheless Västerås was considered the most representative.

Inward and outward commuting increased steadily during and after line upgrades; this was matched by consistently high population growth and generally positive job growth. Ballarat, which has been experiencing steady economic growth in recent years, partly as a result of the Regional Fast Rail project, could expect similar levels of growth in commuting, population and jobs. Given the presence of a well established services sector and traditional industries, job growth would be expected in the short-medium term, in similar step with population.

Moe-Köping

City	Köping	Moe
Population (city)	17,743 (municipality 24,905)	15,582
Dist from capital	147	135
Current travel time	Average 1:17; minimum 1:11	Average 1:52; minimum 1:39
New travel time		1:08-1:16
Economic sectors	Manufacturing, processing, trade	Coal, electricity, dairy industries, tourism
Transport access	Mälaren line, adjacent to E18 road	Traralgon line, adjacent to M1 freeway
Railway station	Central-south	Centrally located

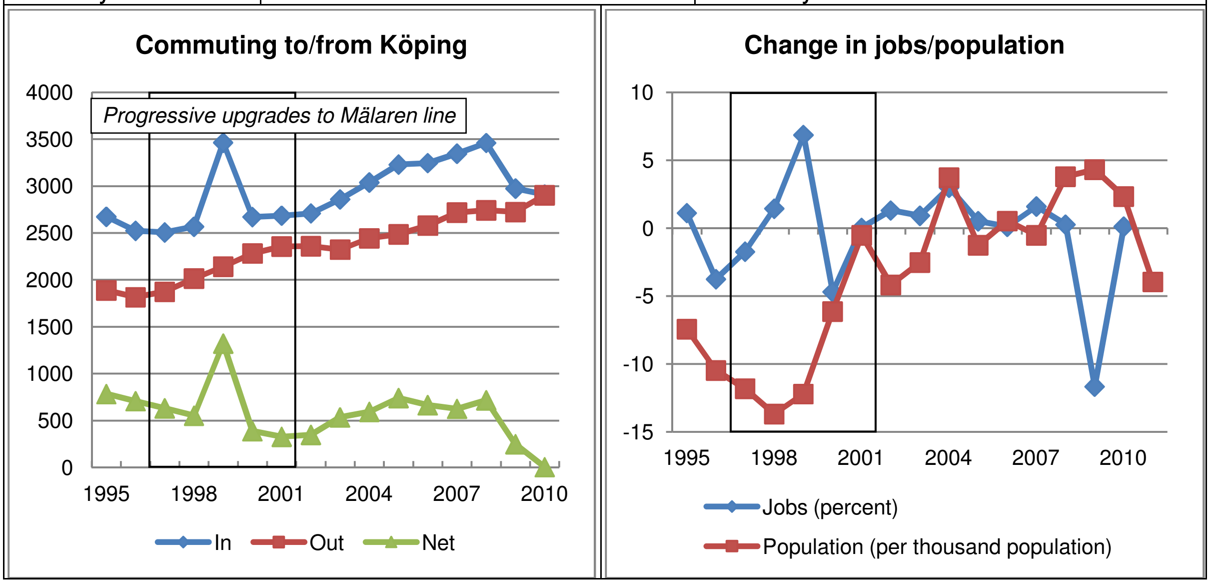


Figure 5.27: Moe-Köping city pair summary (Source: SCB, 2012)

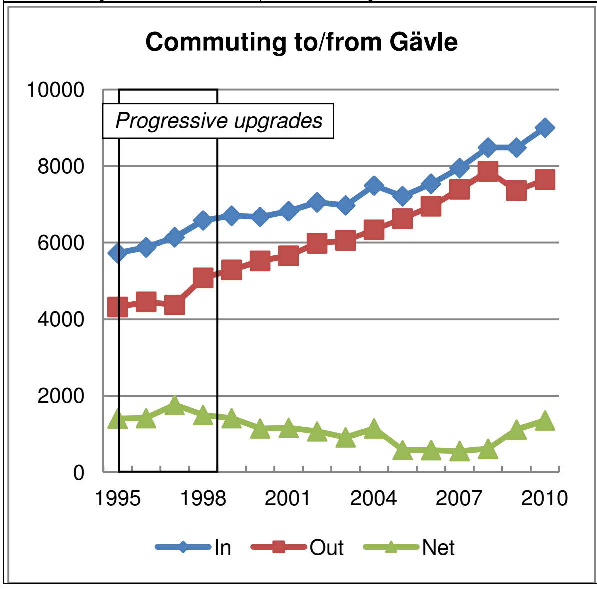
Moe and Köping are very similar in terms of population size and distance from the capital; both also possess well established industries (Moe geared more to primary industry, Köping more to manufacturing) and lie within an industrial belt of cities in their respective regions.

Köping has experienced steadily growing inward and outward commuting during and in the years following line upgrades; after an initial period of sustained negative growth (prior to completion of the upgrades), population settled and fluctuated between 0 and +5‰ growth. Job growth has remained flat or marginally positive, except for a sudden drop in 2009 (linked to external factors), which was followed by negative population growth 1-2 years after. While population and job trends haven't been as positive as in other cities, the advent of high-speed rail appears to have helped stabilise the prevailing negative trends.

While economic performance and population growth is largely linked to the local economies, the introduction of high-speed rail is observed to have a positive influence on the longer-term population and job trends. Moe (and other small-medium sized cities/towns 120-150 km from Melbourne with an industrial base) could therefore expect to benefit from rail improvements.

Shepparton-Gävle

City	Gävle	Shepparton
Population (city)	71,033 (municipality 95,055)	50,373
Dist from capital	175	189
Current travel time	Average 1:28; minimum 1:24	Average 2:29; minimum 2:24
New travel time		1:14-1:25
Economic sectors	Paper & packaging, logistics, IT	Agriculture and assoc. manufacturing
Transport access	East Coast Line, adjacent to E4 road	Shepparton line, highway junction
Railway station	Centrally located	Centrally located



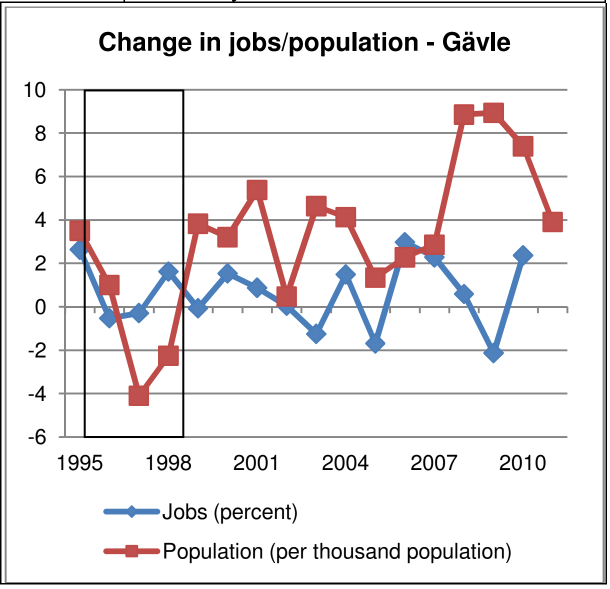


Figure 5.28: Shepparton-Gävle city pair summary (Source: SCB, 2012)

Shepparton and Gävle are located at approximately the same distance from their respective capitals, although Gävle is a coastal city with a somewhat larger population than Shepparton, which is located inland. Gävle supports a broader range of industries that are oriented around logistics and communications, while Shepparton's industries are oriented around agriculture. Both cities are overwhelmingly dominant centres in their regions, which host several smaller towns in the periphery.

Gävle has experienced consistently increasing inward and outward commuting following line upgrades; it has been matched by consistently positive population growth and fluctuating but overall marginally positive job growth; it may be too early to see the delayed effect of jobs growth which is likely to follow population growth some years later. Shepparton could expect similar growth trends, although possibly lower since it's predominantly agricultural industries employ a less mobile workforce than a mixed industry-services sector present of Gävle.

Brief comments on other city pairs

Kilmore-Läggesta (Mariefred): Kilmore and Mariefred are historic towns of similar size and distance from the capital; Mariefred is part of Strängnäs municipality and it is therefore not possible to analyse its specific recent commuting and development patterns.

Geelong-Uppsala: Both cities are the next largest after their respective capitals and have large diversified economies. Uppsala has had a good rail transport supply since 1990 with marginal supply improvements and it is thus difficult to isolate the effects of high-speed rail. It reports strong growth in commuting, jobs and population between 1995 and 2010.

Castlemaine-Kungsör: Castlemaine is slightly closer to its capital and has a higher population than Kungsör. Kungsör achieves relatively modest travel times (1:25-1:28) given its distance from Stockholm, accompanied by negative population growth but positive job growth; this contrasts to the expected time improvements to Castlemaine (0:51-0:59), which is within the commuter band and has a higher growth potential, rendering the pair a poor comparison.

Bendigo-Norrköping: Both medium-sized cities are almost identical in size and location from their capitals; Norrköping is in close proximity to the large regional city of Linköping, while Bendigo has no such near sister city. Norrköping reports stable positive growth in population and jobs and very high growth in outward commuting; its proximity to Linköping offsets the higher than acceptable commuting time to Stockholm. The Bendigo-Norrköping pair may be compared to Ballarat-Västerås, despite the former being larger and further from the capital; on this basis, Bendigo could expect strong growth in population and jobs in the short-medium term with further supply improvements.

Morwell-Arboga: Both small cities are located in industrial belts, although Arboga has a more diversified industrial sector than Morwell, which is oriented around the coal mining. Arboga achieved modest inward and significant outward commuting growth and, although overall population and job growth was negative for 1995-2010 (largely on account of Volvo leaving Arboga in 1997), the population has stabilized and positive job growth is emerging.

Benalla-Hallsberg: Benalla is larger and has a more diversified industrial sector (agricultural support services, tourism and aviation) than Hallsberg, which is chiefly a station town based around the railway. Hallsberg experienced moderate growth in commuting, close to zero job growth and negative population growth, possibly to the gain of the larger nearby city Örebro. It is unreasonable to assume similar effects for Benalla given its extensive local economy and important location on key interstate rail and road routes, and hence high growth potential.

Summary

For each city pair, the Mälardalen city reported strong growth in commuting and positive (or recovering to positive) growth in population and jobs after the introduction of high-speed rail, reflecting a structural change in the labour and housing markets due to increased accessibility with positive effects on regional development. Similar effects could be expected for regional-Victorian counterpart cities: high-speed rail provides increased accessibility, which generates more commercial activity, thus contributing positively to regional development.

5.5.3 Supportive strategies for regional development

Support strategies for high-speed rail employed in the Stockholm-Mälaren region include the coordination of high-speed services with local public transport, station redevelopments, and the relocation/establishment of public institutions in regional cities. They complement rail by allowing seamless shorter journeys that encourage commuting and improve the attractiveness of regional centres for businesses to establish and people to settle. Additional strategies might be needed to facilitate a system of regional cities, which did not eventuate as expected in the centre-west Mälaren valley. This may be especially important for smaller cities/towns greater than one hour from the capital Melbourne with which they experience less interaction.

This section outlines some supportive strategies based on the Stockholm-Mälaren region and literature sources that might be employed in conjunction with high-speed rail services to aid and hasten regional development in Melbourne-regional Victoria.

Coordination with local public transport

While car is the overwhelming mode of local transport in Melbourne-regional Victoria, most regional centres have some degree of local public transport connecting residential areas with the railway station and central commercial areas. Local bus services are assumed currently to align with rail services, particularly for the more infrequent services. Regional rail tickets can be used on local buses (excluding privately operated services) for travel to and from Geelong, Ballarat, Bendigo, Traralgon, Moe and Morwell (V/Line, 2012). Combined ticketing could be extended to other regional towns and cities to encourage public transport commuting.

The future introduction of more frequent high-speed rail services may prompt additional bus feeder services to and from the station. If there is insufficient demand to justify the running of buses needed to serve all train departures, the bus network might be redesigned with fewer lines and higher frequencies, as in the Västerås 'Smartkol' project. Bus infrastructure should be improved where necessary to allow easier movements and shorter travel times and permit seamless transfers with high-speed rail services. Acknowledging the dominance of the car for local transport around regional centres, sufficient car parking space for commuters should be provided at stations, as the case study for the Mälardalen city of Strängnäs revealed.

Station redevelopment

The potential for redevelopment of station areas for commercial and residential development depends on the proximity of the station to the city/town centre, availability of adjacent space and appropriateness for development in view of the effect on existing commercial areas. As the literature points out, centrally located stations are more attractive to commuters and firms seeking to establish than peripheral stations. Fortunately, stations in regional Victoria centres are almost exclusively located in or very near to the city centre and are thus already ideally suited to commuting and private travel and ripe for development where it permits.

A future introduction of high-speed services should (where possible) use the existing stations, since these have the highest potential to attract commuters and new firms, particularly in the emerging services and knowledge sectors. Where new peripheral stations are required due to infrastructure constraints, high quality public transport links should be provided between the station and town centre for seamless commuting; commercial development, which could be attractive due to lower land prices and available space but which might not necessarily take off by itself, may need to be encouraged through non-market measures and incentives.

The Stockholm-Mälaren city case studies addressed two different station types earmarked for redevelopment. Västerås station, which is centrally located in a large regional city but under capacity and severed from the city centre by busy roads, will be rebuilt with improved links and surrounding commercial and residential development on former industrial and municipal land. Strängnäs station, which is located between two small commercial centres (one being the 'city centre'), will be rebuilt exclusively as a travel area with improved access to nearby centres which are reached by foot in under ten minutes or by bus. The examples demonstrate that the type of station development depends on the city and surroundings and there is no model that fits all; the common element to both redevelopments is improved access to/from the city centres and public transport connections/parking to enable effortless travel, regardless of the level of development around the station area. The redevelopment of stations needn't involve their demolition and rebuilding as the examples suggest; many stations are heritage buildings that add to the city's character and should be retained with necessary refurbishments and capacity enhancements to match the modern high-speed rail services they serve.

Establishment and relocation of public institutions

The relocation of government departments and jobs from Melbourne to regional centres was initiated as part of a decentralisation policy of the previous state government in 2010 (Austin, 2010); it is unclear to what extent it has been executed (several departments have successfully been moved) and its status under the current government. Nonetheless, it is a strategy that has been accepted as a means of shifting population to the regions, as it was in the Stockholm-Mälaren region, and could be executed at a larger scale to achieve more rapid growth. The selective relocation of specialist departments, such as energy, health and resources to regional centres could assist in developing regional competencies the centres can build on.

Regional Victoria is home to a few universities, most of which are smaller campuses of large Melbourne based universities. Taking Mälardalen University in Sweden as an example, new universities could be established in centres of regional Victoria; they might orient themselves around traditional local industries and/or emerging energy and technology sectors and build up regional competencies, in a similar way for example the city of Uppsala has established itself as a leader in medical research and technologies. Extending the strategy further, one or two major Melbourne universities could be gradually relocated to several regional centres.

5.5.4 Development via regional competencies and city networks

Among the different complementary measures for high-speed rail, two key instruments stand out in the literature as having the greatest potential to support regional economic development and reduce regional disparities: economic specialisation, through the development of regional competencies, and the formation of regional city networks.

Regional competencies (economic specialisation)

Regional Victoria is acknowledged as a significant contributor to the economic prosperity of the state through its agricultural, manufacturing and tourism industries (DoT, 2008). Its future economic prospects depend on the sustainment of the traditional sectors and the development of new service industries. The location of key industries is depicted in Figure 5.29.

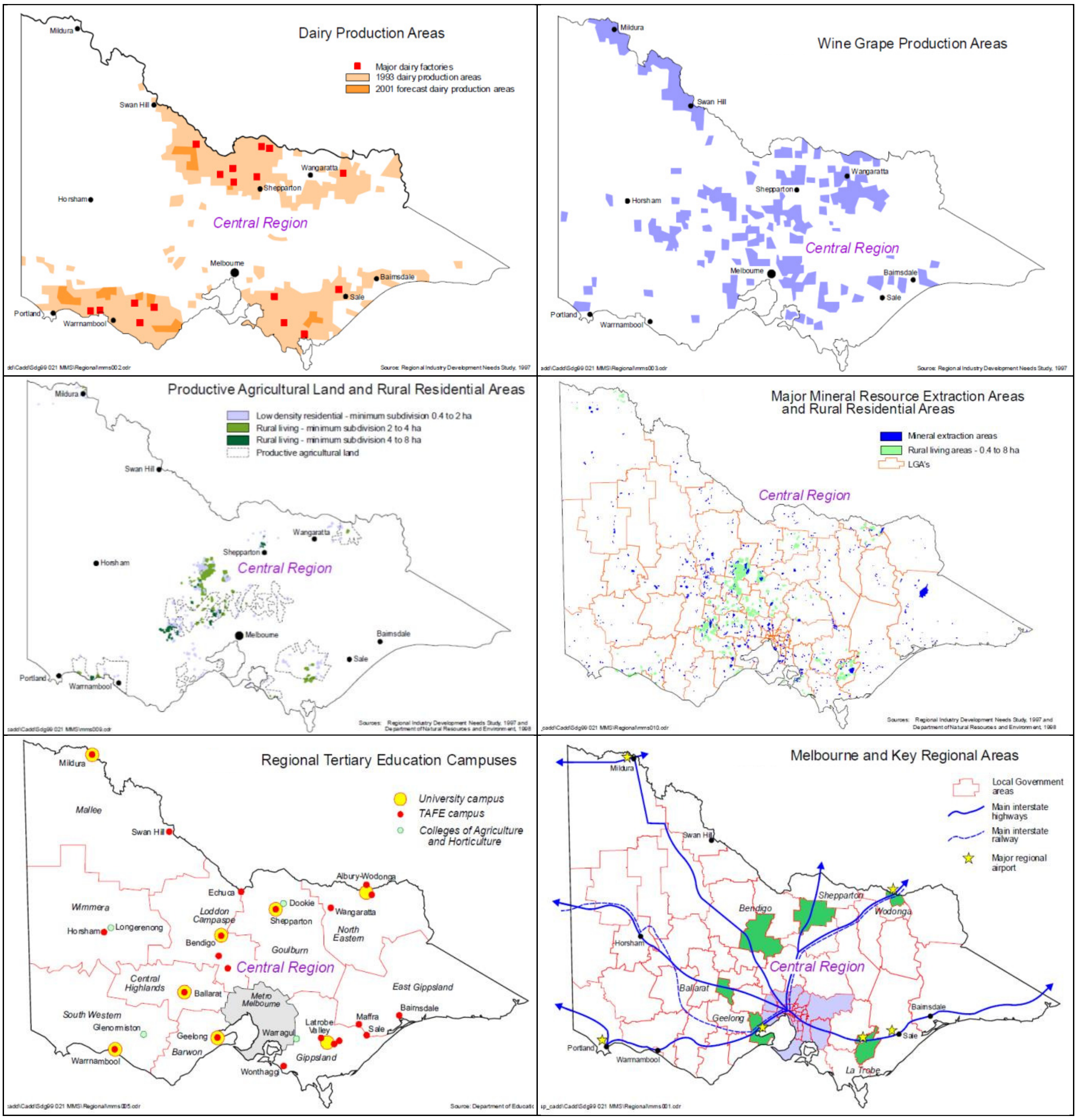


Figure 5.29: Location of industries in regional Victoria
Source: Department of Infrastructure (2001)

As the literature confirms, regions that maintain a comparative advantage in certain economic sectors are more likely to prosper from the accessibility benefits of high-speed rail; otherwise their economic activities are likely to be drained away by the more productive centres. The different regions should therefore concentrate on the sectors in which they have a competence or that depend on the natural resources of which they are endowed. Table 5.17 summarises the important established and emerging economic sectors of the different sub-regions; the list is non-exhaustive and various smaller industries not listed are active in different regions.

Table 5.17: Economic sectors, regional Victoria
Source: Department of Infrastructure (2001)

Sub region	Manufacturing	Primary industries	Services
Geelong	High knowledge: motor vehicles & parts, industrial machinery, textiles and clothing	Wine	Tourism, university
Ballarat		Wine	Tourism, university, telecommunications
Bendigo		Mining, mine	Trade, tourism, university, banking, communications
Albury/Wodonga		Wine	Trade, university campus
Shepparton	Food processing & packaging	Horticulture, dairy, wine	Uni. campus, tourism
Gippsland	Mining industries	Mining, hort., dairy, wine	Uni. Campus, finance
Warrnambool		Horticulture, dairy	Trade
Swan Hill, Mildura		Horticulture, dairy, wine	Trade

The emergence of high-technology industries and knowledge-based services are probably the most important in terms of their propensity to generate jobs and benefit from improved (high-speed rail) transport; growth industries that have been identified include biotechnology, nano-technology, information and communications technology, international education, financial services, aviation and defence (DIIRD, 2008). Regions could also concentrate on innovative industries that complement existing traditional industries (e.g. biotechnology for agriculture) or establish emerging industries such as renewable energies and medical technologies, which might be developed in conjunction with local universities.

Networked cities

The literature theorised that a number of small-medium sized regional cities could be linked together (by high-speed rail) to create an expanded functional corridor with increased intra-regional accessibility and synergy that can compete effectively with larger cities. A 'system of cities' would require links of similar quality between one another as to the capital to gain the necessary accessibility to form a single functional unit; this implies that in addition to the existing fast rail corridors (emanating from Melbourne), improved links are required beyond the large regional centres to the more distant cities and towns, as well as cross-regional links connecting the major centres of fast rail corridors. In reference to section 5.4 on infrastructure improvements for high-speed, it corresponds to improvements to outer regional lines and the construction of peripheral line(s), as suggested in Figure 5.24. Over time, a web-type network could evolve with much improved inter-regional accessibility, as depicted in Figure 5.30.

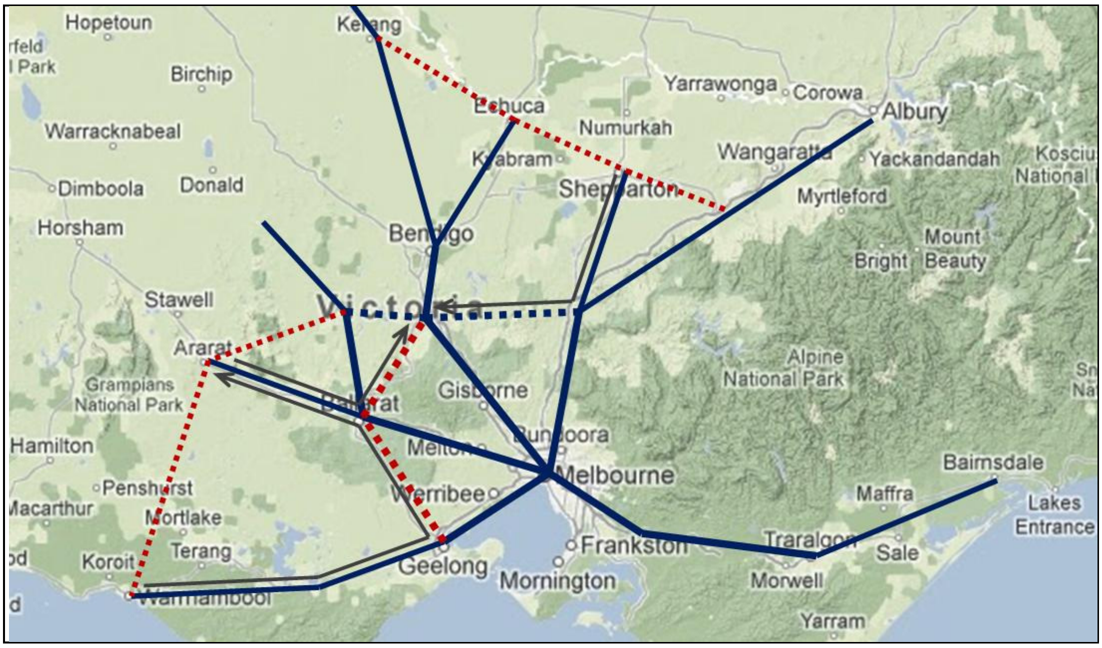


Figure 5.30: 'Networked cities' by high-speed rail concept
Map source: Google Maps (2012)

Inbakaran and Harwood (2006), in their study of work patterns in regional Victoria, report a low volume of work journeys between the four regional areas of Ballarat, Bendigo, Geelong, and Latrobe Valley, of which proximity is a key factor and car the main mode. The addition of peripheral (high-speed rail) links between regional centres would appear a useful (perhaps necessary) instrument to facilitate inter-regional work travel; they should be built to the same speed as the inner regional lines (200-250 km/h) and have ≤ hourly frequency in peak times.

The 'networked cities by high-speed rail' concept could be developed in three stages: the first stage would involve improvements to existing inner lines (to 200-250 km/h) and outer lines (to 160 km/h), linking regional cities and towns along existing rail corridors and improving the travel time between the large regional cities and the capital Melbourne; the second stage would involve building peripheral lines between the regional centres, improving connectivity between complementary regional centres on existing corridors and facilitating inter-regional corridor travel and commuting; the third stage would involve the upgrade of outer line arteries to higher speeds (200-250 km/h), increasing the possibility for commuting from outer regions to Melbourne and between outer regional centres on different corridors; typical commuting movements between regions that might be expected are indicated by arrows on Figure 5.30. In parallel, additional links could be added between regional cities and smaller towns that are currently not located on a rail corridor but which have a strong growth potential; extensions might also be considered in the western regions of country-Victoria.

A longer-term strategy is to build outer peripheral lines to connect the more distant regional centres; it is acknowledged that such links are usually too costly in relation to the benefits and they would only be considered once significant population growth had been achieved in outer centres and there was sufficient work-related travel demand to justify their investment.

5.5.5 Environmental implications of transport/spatial changes

It was suggested at the beginning of the thesis that regional development via high-speed rail may generate positive environmental effects. The literature reviewed supports this view to the extent that the move to a polycentric city structure and the dispersion of economic activity to peripheral regions reduces the external costs of congestion and environmental degradation in low density metropolitan areas of large cities and reduces commuting time and the quantity of intra-city travel along with the adverse environmental effects. These conclusions are valid in terms of intra-city travel but neglect likely increases in the extent of inter-city commuting that will result from improved transport links and a dispersed economic structure. It is beyond the scope of this thesis to conclude whether a high-speed linked polycentric structure is more or less environmentally friendly than a monocentric structure, as it is dependent on the relative changes in commuting and travel by mode, and other factors including city density, structure, extent of car use and dependence, etc; it is also time-dependent. Nevertheless, changes in the spatial structure and associated environmental implications can be theorised.

For Melbourne-regional Victoria, the environmental implications of change are positive when considering the other factors: Melbourne is a low-density city that is highly auto-dependent. Some general remarks can be made on the spatial changes and transport and environmental implications of a move to a high-speed linked polycentric (economically dispersed) structure, assuming complementary measures are taken in parallel.

In the short-term:

- The introduction of high-speed rail services will induce increased commuting between Melbourne and the regional centres (and between the regional centres themselves) due to reduced travel times and increased accessibility, including some shift from car.
- The environmental consequences of increased inter-city commuting depend on energy source (diesel or electric, electricity source) and efficiency of rail services (operating efficiency and passenger/seat load factor); for example, a modern rail service powered from renewable/low carbon sources and achieving a high average load factor (e.g. 60%) is cleaner and more efficient than a service with diesel trains and low load.
- There will be some reduction in intra-city commuting within Melbourne due to: offset by increased inward commuting from regional centres; movement of some Melbourne residents to regional centres with some accompanying inter-city commuting.

In the long-term (relative to population growth):

- The long-term effects are reflective of the positive effects described in the literature as a result of spatial changes and, in particular, less intra-city (auto) commuting/travel.
- The movement of economic activity to the regions is accompanied by the movement of residents who avail of more attractive lifestyles and proximity to jobs. As a result, new intercity commuting patterns will emerge depending on the location of residences in relation to workplaces (increasing or decreasing); intra-city Melbourne commuting will reduce in accordance with the movement of economic activity to the periphery.

- As regional centres grow, there will be an increase in local commuting; however this will be infinitely smaller than the comparative reduction in Melbourne commuting due to much smaller city sizes and (presumably) sustainable planning principles adopted.
- Speculative: there will be a stabilisation in population movement (linked to proximity to employment and favouring a net movement to the regions), leading to stabilisation of (or possibly reduced) inter-city commuting.

The time-dependent effects represent a cycle of regional spatial change, whereby high-speed rail acts as a means of facilitating the movement of populations and economic activity from the capital Melbourne to regional-Victorian centres; this is mirrored by a reduction in car use and a comparatively lower increase in public transport (high-speed and local-regional) use. To summarise: in the short-term there will likely be an increase in the amount of commuting and travel (induced travel by regional high-speed rail) notwithstanding some shift from car to rail; in the longer term there will be a gradual decrease in the share of car travel that accompanies the shift of population and economic activity to regional areas which, due to their size and structure, necessitate much less local commuting and local travel than the capital Melbourne. Reduced car travel (and fossil fuel use) and associated externalities are expected to make the greatest contribution to positive environmental effects.

The sequence of change is represented by the following Table 5.18.

Table 5.18: Temporal sequence of transport/spatial change and environmental effects

Time frame	Short	Medium	Long
Inter-city commuting by reg. HSR and car	Initial increase in HSR Stable or reduced car	Stabilising reg. HSR Reducing car	Stabilised reg. HSR
Core city commuting	Stable	Reducing	
Spatial change	Gradual movement of population and eco. activity from core to periphery		
Environmental impact	Negative or neutral	Reducing	Much reduced (+)

Sustainable planning principles for developing regional centres

The negative environmental effects of development in regional areas can be reduced (and the overall positive effects of change heightened) by employing sustainable planning and design principles; these are associated with efficient use of energy and water, renewable energies, reduction in car dependence through providing access to good quality local public transport, and encouraging development around city centres in which the railway station is the centre of activity. Small cities are proposed as a sustainable alternative to an expanding Melbourne metropolis and solution to its growth challenges, boasting potential positive socio-economic and environmental effects (Reale, 2009; Bayley, 2011); these cities should be self-sufficient from the outset, based on diversified economies, water and energy independent, planned with infrastructure for a defined maximum load, transit oriented (with access to high-quality public transport), surrounded by green areas and walkable. Concentration of development (especially workplaces) in the immediate proximity of the stations would lead to high exploitation over a limited area with positive environmental effects (less travel, efficient energy use, etc).

Possibilities for rail freight

While this thesis is focussed on passenger transport, possibilities for rail freight development should also be mentioned given that the improvements proposed will also provide additional capacity to rail freight. The shift of freight from road to rail has positive environmental effects due to the capacity of rail to haul much greater loads than road and thus reduce the amount of energy consumed per tonne; such 'economies of scale' are also efficient in terms of transport cost. The possibility of line electrification, as proposed in the various 'high-speed' scenarios, offers the possibility to electrify rail freight; this not only reduces local vehicle emissions, but enables energy to be potentially sourced from emerging green energies. Further, electric rail vehicles offer a higher power to weight output, enabling greater quantities to be hauled faster.

As previously mentioned, freight in Victoria is overwhelmingly road based: rail holds a 15% market share of interstate and local interregional freight (VFLC, 2010); freight flows for road and rail are depicted in Figure 5.31. Road freight is concentrated on the key regional corridors stemming from Melbourne and rail freight is concentrated in the western regions of the state and around the ports of Portland, Geelong and Melbourne. The most significant export cargos in terms of weight are petroleum products, dairy products, grain, fruit and vegetables. Import commodities include fertilisers, reflecting the strong links with rural and regional Victoria. (DoI, 2001) The nature of the cargos (more agricultural and semi-processed than heavy mass) suggests rail could be a promising alternative mode, especially transporting at higher speeds.

Lindahl (2001) discusses the consequences of different types of rail freight operations from a track geometry perspective, categorising freight trains according to load type:

- Category I: Freight trains for heavy mass goods (incl. containers): 90-120 km/h
- Category II: Fast freight trains for unit-loads, heavy express goods: 160-180 km/h
- Category III: Freight trains for light express goods or mail: 200-300 km/h

Transport of containers and swap bodies may in the future be transferred to lighter and faster category II freight trains capable of higher speeds. An emerging market for high-speed freight, along with classic freight, has the potential to exploit an expanded high-speed network.

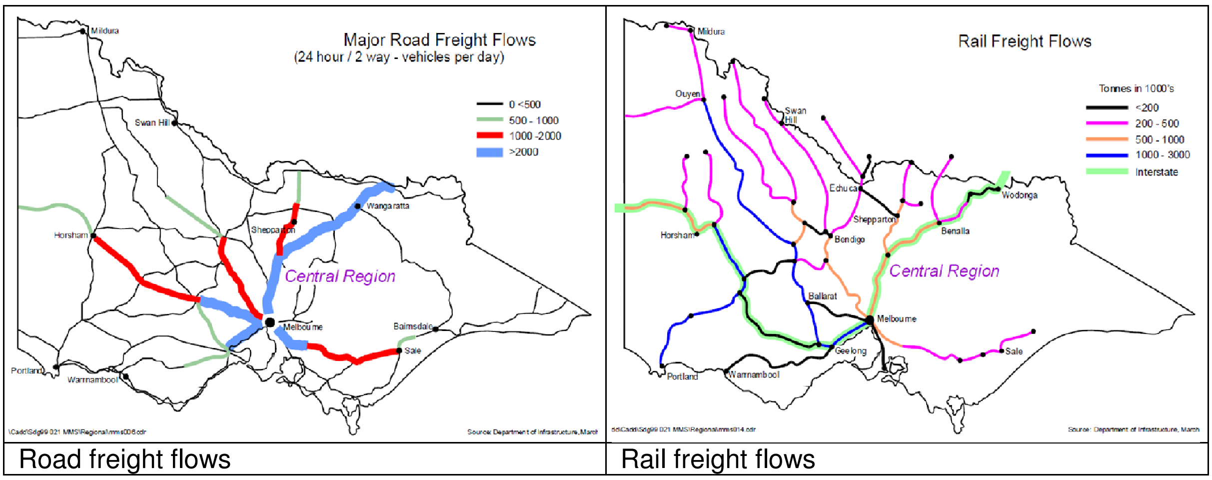


Figure 5.31: Road and rail freight flows in Victoria
Source: Department of Infrastructure (2001)

6 SUMMARY AND CONCLUSIONS

This chapter summarises the outcomes of preceding chapters and draws general conclusions on the possibilities for regional high-speed rail and its implications for regional development in Melbourne-regional Victoria. A recommendation on the way forward is also suggested.

The goal of this thesis was to examine, based on a study of the regional high-speed corridors in the Stockholm-Mälaren region, how high-speed rail could be applied to regional corridors in the Melbourne-country Victoria region of Australia and what the short-term transport-related and medium-long term regional effects might be. Given the geographic similarities of the two regions, the Stockholm-Mälaren region was used as a basis for the future application of high-speed rail in Melbourne-regional Victoria and its expected long-term regional effects.

6.1 Regional development in the Stockholm-Mälaren Region

A study of the Stockholm-Mälaren region examined the transport-related and emerging long-term regional development effects on regional corridors where high-speed rail was introduced. Regional high-speed services operate with frequencies of around one hour and cover journey times up to 1.5 hours (150-180 km) from Stockholm with speeds of up to 200 km/h.

6.1.1 Transport-related effects based on Svealand line

A study of the effects of high-speed on travel patterns took the Svealand line as a well studied representative case for the region; it achieved a seven-fold increase in travel demand and the capture of around 30% of the regional transport market based on a 40% reduction in travel time and a doubling of service frequency through the introduction of high-speed trains. While similar effects predicted on the other high-speed lines can't be verified, a subsequent study of commuting patterns revealing similar increases suggests the Svealand line is representative. A closer look at commuting patterns reveals a considerable increase in outward commuting to Stockholm for cities within an hour's journey time and strong growth in inward commuting from neighbouring regions; positive population and job growth matches these trends.

6.1.2 Longer-term regional effects

The emergence of longer-term regional development effects is identified through changes in commuting patterns supported by changes in population and jobs, based on the assumption that growth in outward commuting signals increased in-migration as new residents move into the region and commute to their current jobs; and growth in inward commuting signals an increase in economic activity as businesses establish in the region and workers commute in.

A brief study of city groups of similar population and distance from the capital identified the positive influence of regional high-speed rail, indicated by sharply increasing out-commuting, slower but gradually increasing in-commuting, and matched by varying levels of population and job growth. An overview of cities across the wider Stockholm-Mälaren region confirmed these effects over a greater geographic range. Larger cities around one hour from Stockholm achieved sustained positive growth in outward commuting accompanied by steady population growth and flatter but positive growth in inward commuting matched by positive job growth; this signals the arrival of new residents who commute to jobs outside, particularly Stockholm, and emerging local economic growth with workers willing to commute in from neighbouring areas. The strong performance highlights the positive influence of shorter travel times to/from Stockholm and reflects the fact that larger cities benefit from an already strong local economy for which high-speed rail has a facilitating effect. Smaller cities within an hour of Stockholm experienced similar positive effects, with job growth outmatched only by the larger cities.

Small-medium cities further than one hour from Stockholm had mixed performance with an average overall decline in jobs and population; although as the city groups study found, there is evidence of a recovery to neutral or positive growth in later years, indicating the delayed effect of rail improvements on regional development over external factors. The conclusion for these mixed-performance cities is that, while the trends in recent years are promising, it is too early to conclude on the longer-term effects of high-speed rail on their development; further, additional supporting measures may be needed to improve their growth prospects.

The three city case studies (Västerås, Strängnäs and Arboga) addressed regional development from the viewpoint of the municipalities and gained an appreciation of the types of supportive strategies under consideration. The introduction of regional high-speed was viewed positively considering increased accessibility and commuting, generally positive population growth and arrival of new economic activity. Supportive strategies needed to reap the benefits of regional high-speed include: coordination with public transport, station redevelopment, establishment of public institutions and non-transport measures supporting increased inter-city exchange.

6.1.3 Summary of outcomes of Stockholm-Mälaren region study

The main outcomes of the Stockholm-Mälaren region study are summarised as follows:

- All regional centres with a high-speed connection experienced increased commuting and a degree of population and job growth; growth in outward commuting was greater than inward, reflecting movement to the regions and commuting to Stockholm.
- Cities within one hour of Stockholm experienced the greatest increase in commuting that was matched by consistently positive population and emerging job growth; these centres have benefited the most from high-speed, which reinforced current activities.
- Small-medium cities greater than one hour from Stockholm suffering population and job decline experienced recovery to neutral or positive growth with the introduction of high-speed; these centres depend on supportive strategies to fully capture its benefits, particularly those that foster inter-city exchange and formation of city networks.

6.2 High-speed rail possibilities in Melbourne-regional Victoria

Regional high-speed rail was proposed as a means to markedly increase accessibility between Melbourne and the regional centres (and between the regional centres themselves) in order to facilitate increased inter-city commuting and raise the potential for regional development.

6.2.1 Current network and limitations

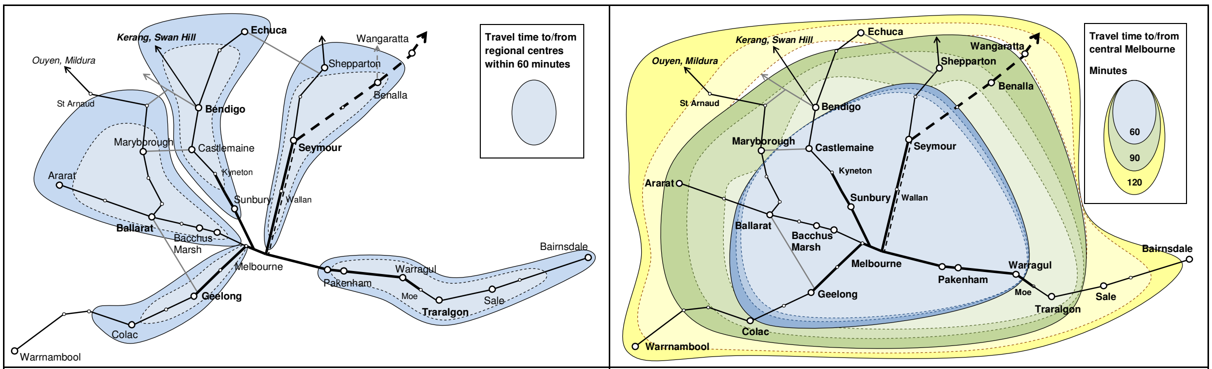
A review of the current rail network and services revealed an already solid fast regional rail system between Melbourne and the larger regional cities (with speeds of up to 160 km/h and hourly frequency) but weaker outer services beyond; inner regional services are compromised by capacity limitations, mainly due to the extent of single track and lower speeds on passing sections. Only the regional city of Geelong is currently within the acceptable commuting time of one hour of Melbourne; Ballarat and Seymour are slightly beyond one hour for their fastest services but average times are significantly longer. The lack of acceptable commuting times to and from Melbourne for all but a few trains on 2-3 lines is considered a major hindrance to the development of inter-city commuting and exchange. Freight possibilities are also limited.

6.2.2 Speed enhancements for reduced travel time and increased accessibility

To achieve improved accessibility, in particular reduce commuting time between Melbourne and the regional centres and between cities and towns within the regional corridors to within 1 hour, radical improvements were proposed based on various increased speed scenarios and that amount to raising the status of the network to true high-speed; enhancements considered speed intervals of 160, 200 and 250 km/h. Combining different speeds on inner and outer lines enabled assessment of the marginal affects of travel time improvements and identified efficient arrangements in respect of accessibility/economy.

Upgrading the outer lines to 160 km/h proves effective in bringing important outer regional centres within 1.5 hours of Melbourne and, more importantly, all cities and towns in regional corridors within 1 hour of their main regional centre; this is an important accomplishment for intra-regional accessibility and contributes to the formation of city networks that complement regional development; further enhancements to 200 and 250 km/h bring relatively marginal improvements in accessibility over 160 km/h.

Upgrading the inner lines to 200 km/h brings 3 of the 5 large regional centres and a few other important cities to within one hour of Melbourne; a further standard increase to 250 km/h brings marginal improvements but more extensive infrastructure improvements (that raise the average speed) bring 4 of the 5 regional centres (the addition of Bendigo) as well as a few other regional cities and towns to within one hour of Melbourne. All other regional towns and cities are brought to within 1.5 hours of Melbourne, with the exception of Warrnambool and Bairnsdale, which are brought to within 2 hours of the capital. The effects of upgrades to 160 km/h on outer lines and to 250 km/h (standard) on inner lines are depicted in Figure 6.1.



Accessibility to/from major regional centres Inner contours: Current min travel time Outer contours: Increase to 160 km/h	Accessibility to/from Melbourne Improvement to 250 km/hr on inner lines Outer lines: Current; 160 km/h; 250 km/h

Figure 6.1: Accessibility by travel time for different speed scenarios

The upgrade of all lines to highest possible speed (250 km/h) evidently achieves the greatest improvements in accessibility across the region. An efficient short-medium term arrangement might be the upgrade of outer lines to 160 km/h (or greater depending on the marginal cost of improvements) and the inner lines to 200-250 km/h; a special case could be the Bendigo line, which with extraordinary enhancements to 250 km/h speed, brings the major regional city of Bendigo to within one hour of Melbourne to facilitate daily commuting. The requirements for upgrades to high speeds are electrification of the line, new signalling systems and high-speed electric vehicles, which attract higher investment but achieve improved run times; such a step upgrade could be applied not only to the Bendigo line but to the shared 'Regional Rail Link' group: Geeling, Ballarat and Bendigo lines. Table 6.1 indicates the infrastructure and vehicle requirements for upgrades, for which there are some additional line specific requirements.

Table 6.1: Infrastructure and vehicle requirements

Speed	Track	Signalling / control	Vehicles	Electrification
160	Double track (inner lines)	Current signals, TPWS	Current diesel	No
200	Double track; upgrades to sections of existing track	Existing with upgrades	200 kph diesel	No
		New signalling, ATP	Electric, cab sig.	25kV AC
250	Major upgrades to large sections of track	New signalling, ATP	Electric, cab sig.	25kV AC
250+	Substantial track rebuilding	New signalling, ATP	Electric, cab sig.	25kV AC

The estimated passenger growth factor resulting from upgrades varies from 1.3 to 1.5 for the inner lines and 1.5 to 2.0 for outer lines for trips to/from Melbourne and 1.4 to 1.9 for intra-regional trips between cities within corridors. Reflecting the marginal increase in accessibility with regard to speed, the largest growth steps are from 160 km/h to 200-250 km/h on inner lines and from current speeds to 160 km/h on outer lines. This combination thus represents an efficient use of line speeds over the network, balancing economy with accessibility gains. For journeys achieving a travel time of around one hour, the use of higher than normal elasticities yield higher growth factors of 1.9 to 2 for trips to/from Melbourne. Comparing these growth factors to the Svealand line study suggests they may be underestimated by up to 33% in some cases; they represent short-term (static) effects and don't include future dynamic effect gains.

6.2.3 Predicted longer-term regional development effects

Long-term regional development effects are theorised based on the observation of emerging regional effects in the Stockholm-Mälaren region via a comparative city pairing approach, as well as concepts from the literature.

The city-pairing matched pairs of cities from the Stockholm-Mälaren region and Melbourne-regional Victoria with similar population, distance from the capital and scale of economy. A study of the Mälardalen reference cities revealed strong growth in commuting and positive (or recovering to positive) growth in population and jobs after the introduction of high-speed, indicating emerging positive effects for regional development. A similar positive effect can be predicted for the paired Victorian cities with the application of high-speed rail services. As in the Stockholm-Mälaren region city-groups study, large cities with well established diverse economies and located around one hour from the capital (Västerås, Ballarat) are predicted to perform the most strongly, as are small inner commuting towns (Nykvarn, Gisborne). Smaller outer cities and towns that achieved lower job and population growth (Köping, Moe) expect high-speed rail to have a generating or 'catalysing' role, dependent on appropriate supportive strategies that focus on economic specialisation and improving local transport links. Medium outer cities with well established economies (Gävle, Shepparton) can expect steady positive growth with high-speed rail having a 'facilitating' role, reinforcing current activities.

The same supportive strategies identified in the Stockholm-Mälaren region are suggested for Melbourne regional-Victoria, as well as other non-transport measures focussing on economic specialisation through the exploitation of regional competencies and local endowments, and the creation of city networks via improved intra- and inter-regional links and the building of functional complementarities between cities; the creation of city networks seems particularly important if (small-medium sized) regional cities are to be self-sufficient and able to compete effectively with the capital Melbourne rather than remain dependent satellites.

6.2.4 Recommendation: the way forward

Based on the results, this thesis recommends the following steps towards the development of a regional high-speed rail network and polycentric regional structure in the long-term:

1. Upgrading of inner regional rail lines to 200-250 km/h depending on the marginal cost of improvements in respect of accessibility gains; as a special case: upgrade of Bendigo line to 250 km/h with 'special enhancements' to bring Bendigo within 1 hour of Melbourne.
2. Upgrading of outer regional rail lines to 160 km/h (or faster) to bring regional centres to within 1 hour of their regional parent city and also closer to Melbourne.
3. Construction of peripheral lines between regional centres (as indicated in Figure 5.24) to improve connectivity between complementary regional centres on existing corridors.
4. Upgrading of outer lines to 'high-speed' and new rail links to non-connected towns.

Parallel to the rail development, the various supportive strategies identified should be enacted to ensure the benefits of high-speed rail are evenly spread over the region.

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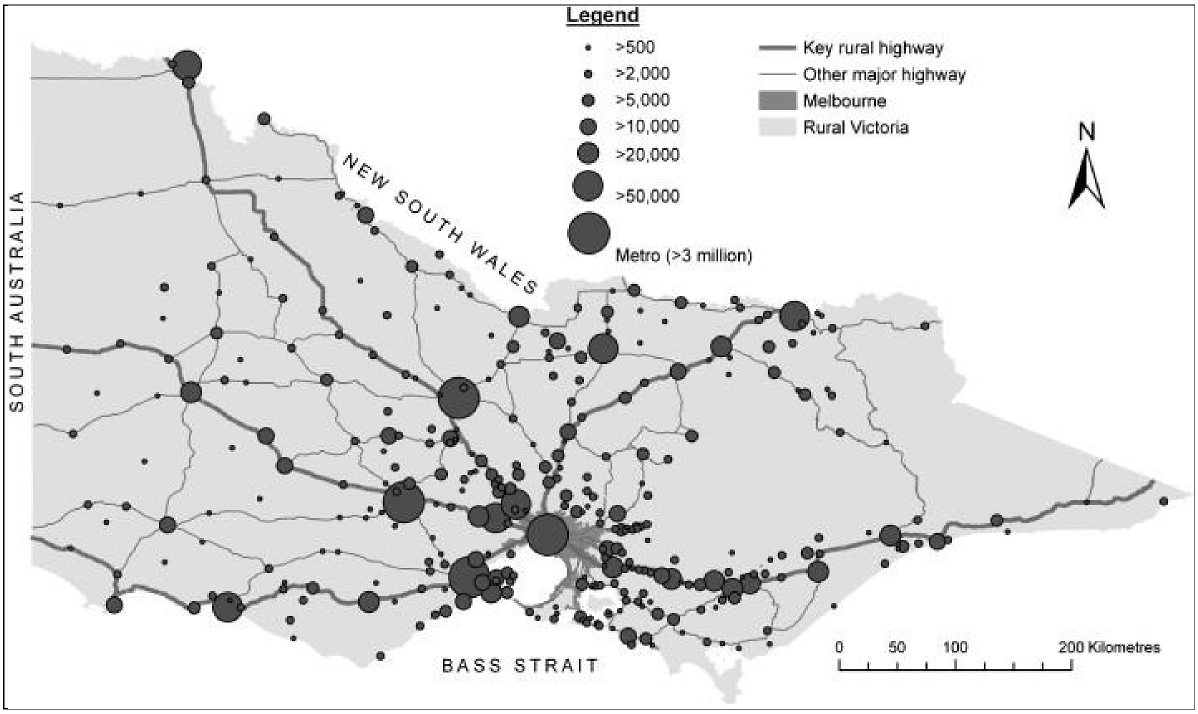
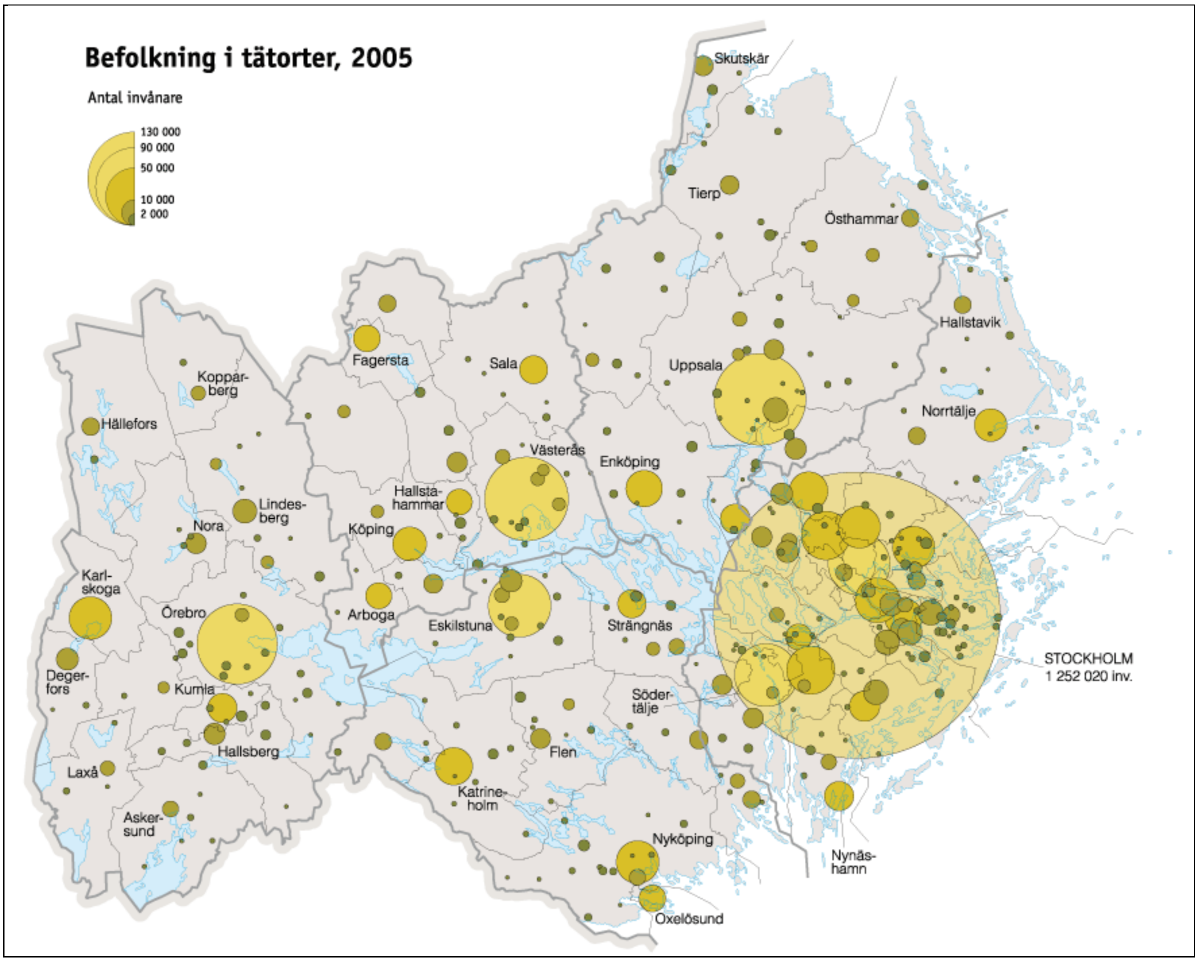
Nilsson, Lennart, Utvecklingsstrateg, Strängnäs kommun. Meeting, 11 May 2012

Appendix 1


Legend
>500
>2,000
>5,000
>10,000
>20,000
>50,000
Metro (>3 million)
Key rural highway
Other major highway
Melbourne
Rural Victoria
N
SOUTH AUSTRALIA
NEW SOUTH WALES
BASS STRAIT
0 50 100 200 Kilometres


Befolkning i tätorter, 2005
Antal invånare
130 000
90 000
50 000
10 000
2 000
Skutskär
Tierp
Östhammar
Hallstavik
Uppsala
Norrtälje
Fagersta
Sala
Koppar-berg
Hällefors
Västerås
Enköping
Hallsta-hammar
Lindes-berg
Nora
Köping
Karl-skoga
Örebro
Arboga
Eskilstuna
Strängnäs
Deger-fors
Kumla
Söder-tälje
STOCKHOLM
1 252 020 inv.
Hallsberg
Flen
Laxå
Katrine-holm
Asker-sund
Nyköping
Nynäs-hamn
Oxelösund

Appendix 2

Mälardalen average speeds

Line	Station	Rail (km)	Minimum travel time		Average	Stops
		distance	Hrs:mins	Mins	speed	before
Svealand	Nykvarn	50	0:28	28	107.1	2
	Läggesta	67	0:38	38	105.8	3
	Strängnäs	83	0:46	46	108.3	4
	Eskilstuna	115	0:53	53	130.2	5
	Kungsör	141	1:25	85	99.5	6
Mälaren	Enköping	72	0:38	38	113.7	2
	Västerås	107	0:50	50	128.4	0
	Köping	141	1:11	71	119.2	4
	Arboga	159	1:22	82	116.3	5
	Örebro	205	1:47	107	115.0	6
East Coast	Uppsala	69	0:37	37	111.9	0
	Tierp	131	1:03	63	124.8	2
	Gävle	182	1:24	84	130.0	2
Western Main Line	Flen	108	0:58	58	111.7	3
	Katrineholm	131	0:54	54	145.6	1
Southern Main Line	Norrköping	163	1:15	75	130.4	1
	Linköping	210	1:39	99	127.3	2
Nyköping	Nyköping	103	1:01	61	101.3	3
Average (not including Nyköping)					119.1	
Weighted average					120.9	

Appendix 3

Regional Victoria average speeds

Line	Stop	Rail (km) distance	Minimum travel time		Average speed
			Hrs:mins	Mins	
Geelong	Geelong	75	0.49	49	91.3
Warrnambool	Colac	155	1.56	116	80.4
	Warrnambool	269	3.13	193	83.7
Bendigo	Sunbury	40	0.32	32	74.1
	Castlemaine	127	1.07	67	114.0
	Bendigo	164	1.27	87	113.3
Echuca	Echuca	252	2.45	165	91.6
Swan Hill	Swan Hill	345	4.19	259	80.0
Ballarat	Bacchus Marsh	53	0.38	38	83.5
	Ballarat	122	1.05	65	112.4
Ararat	Ararat	213	2.15	135	94.6
Maryborough	Maryborough	180	2.12	132	81.8
Traralgon	Warragul	102	1.25	85	71.8
	Traralgon	160	2.03	123	78.1
Bairnsdale	Sale	208	2.42	162	77.0
	Bairnsdale	277	3.37	217	76.6
Seymour	Wallan	47	0.38	38	75.0
	Seymour	102	1.10	70	87.2
Shepparton	Shepparton	185	2.24	144	77.0
Albury/ Wodonga	Euroa	153	1.50	110	83.5
	Benalla	197	2.05	125	94.7
	Wangaratta	236	2.31	151	93.8
	Wodonga	304	3.30	210	86.8

Appendix 4

Speed scenario travel times

Inner line	Avg	160*	160*	200	200	200	250	250	250	250+	250+	Reg
Outer line	Now	Now	160	Now	160	200	Now	160	250	250+	160	160
Geelong	1.01	0.49	0.49	0.34	0.34	0.34	0.30	0.30	0.30	0.26	0.26	0.00
Winchelsea			1.10		0.55	0.53		0.50	0.46	0.40	0.46	0.21
Colac	2.10	1.56	1.29	1.41	1.15	1.12	1.37	1.10	1.02	0.53	1.06	0.40
Camperdown			1.52		1.37	1.33		1.33	1.20	1.09	1.29	1.03
Terang			2.03		1.49	1.43		1.44	1.29	1.16	1.40	1.14
Warrnambool	3.25	3.13	2.26	2.58	2.12	2.04	2.54	2.07	1.48	1.32	2.03	1.37
Melton				0.19	0.19	0.19	0.17	0.17	0.17	0.14	0.14	0.40
Bacch Marsh	0.50	0.38	0.38	0.24	0.24	0.24	0.21	0.21	0.21	0.18	0.18	0.34
Ballan				0.38	0.38	0.38	0.33	0.33	0.33	0.28	0.28	0.20
Ballarat	1.23	1.05	1.05	0.56	0.56	0.56	0.49	0.49	0.49	0.42	0.42	0.00
Beaufort			1.27		1.19	1.17		1.11	1.07	0.57	1.04	0.22
Ararat	2.49	2.15	1.51	2.06	1.42	1.38	1.59	1.34	1.25	1.13	1.27	0.46
Maryborough	2.35	2.12	1.34	2.03	1.25	1.23	1.56	1.18	1.12	1.02	1.11	0.29
Dunolly			1.45		1.36	1.33		1.29	1.21	1.09	1.22	0.40
St Arnaud			2.12		2.03	1.58		1.55	1.42	1.27	1.48	1.07
Sunbury	0.39	0.32	0.32	0.18	0.18	0.18	0.16	0.16	0.16	0.14	0.14	1.02
Gisborne				0.31	0.31	0.31	0.26	0.26	0.26	0.23	0.23	0.49
Kyneton				0.43	0.43	0.43	0.37	0.37	0.37	0.32	0.32	0.35
Castlemaine	1.32	1.07	1.04	0.59	0.59	0.59	0.51	0.51	0.51	0.44	0.44	0.18
Bendigo	1.56	1.27	1.27	1.16	1.16	1.16	1.06	1.06	1.06	0.56	0.56	0.00
Rochester			1.58		1.46	1.44		1.36	1.30	1.17	1.27	0.31
Echuca	3.34	2.45	2.11	2.34	1.60	1.56	2.24	1.50	1.41	1.26	1.40	0.44
Kerang			2.29		2.18	2.13		2.08	1.56	1.39	1.59	1.02
Swan Hill	4.41	4.19	2.58	3.26	2.46	2.39	3.22	2.36	2.18	1.58	2.27	1.31
Pakenham				0.42	0.42	0.42	0.38	0.38	0.38	0.35	0.35	0.51
Drouin				0.57	0.57	0.57	0.51	0.51	0.51	0.46	0.46	0.35
Warragul	1.36	1.25	1.25	1.02	1.02	1.02	0.56	0.56	0.56	0.50	0.50	0.29
Trafalgar				1.11	1.11	1.11	1.04	1.04	1.04	0.57	0.57	0.19
Moe				1.16	1.16	1.16	1.08	1.08	1.08	1.00	1.00	0.14
Morwell				1.23	1.23	1.23	1.14	1.14	1.14	1.05	1.05	0.07
Traralgon	2.18	2.03	2.03	1.29	1.29	1.29	1.19	1.19	1.19	1.10	1.10	0.00
Rosedale			2.14		1.40	1.39		1.30	1.28	1.18	1.21	0.11
Sale	3.00	2.42	2.27	2.08	1.53	1.51	1.58	1.43	1.38	1.26	1.34	0.24
Stratford			2.35		2.01	1.58		1.51	1.45	1.32	1.42	0.32
Bairnsdale	3.46	3.37	3.01	3.03	2.27	2.23	2.53	2.17	2.06	1.50	2.08	0.58
Wallan	*0.45*	0.38	0.38	0.22	0.22	0.22	0.19	0.19	0.19	0.16	0.16	0.27
Kilmore				0.30	0.30	0.30	0.26	0.26	0.26	0.22	0.22	0.18
Broadford				0.36	0.36	0.36	0.31	0.31	0.31	0.26	0.26	0.12
Seymour	1.25	1.10	1.10	0.47	0.47	0.47	0.41	0.41	0.41	0.35	0.35	0.00
Nagambie			1.23		1.00	0.59		0.54	0.51	0.44	0.48	0.13
Shepparton	2.39	2.24	1.52	2.01	1.29	1.25	1.55	1.22	1.14	1.03	1.16	0.42
Numurkah			2.07		1.44	1.39		1.37	1.26	1.14	1.32	0.57
Tocumwal			2.25		2.02	1.56		1.56	1.41	1.26	1.50	1.15
Euroa	2.06	1.50	1.36	1.27	1.13	1.11	1.21	1.06	1.01	0.52	1.01	0.26
Benalla	2.28	2.05	1.58	1.42	1.35	1.31	1.36	1.28	1.19	1.08	1.23	0.48
Wangaratta	2.55	2.31	2.17	2.08	1.54	1.49	2.02	1.48	1.34	1.21	1.42	1.07
Chiltern			2.36		2.13	2.06		2.06	1.49	1.34	2.01	1.26
Wodonga	3.52	3.30	2.51	3.07	2.28	2.20	3.01	2.22	2.02	1.44	2.16	1.41
Albury			2.54		2.31	2.23		2.25	2.04	1.46	2.19	1.44

Appendix 5

Passenger growth by demand elasticities (Example: 250 km/h inner lines, 160 km/h outer lines)

250 inner	Avg travel time		No of	Freq	Upg TT	Improv-	LB	LB	UB	UB	% inc	New	% chg	% inc	Tot inc	Urban	Weight
160 outer	Mins	hh.mm	deps	mins	mins	ement	31-120	>120	31-120	>120	TT red	freq	in freq	in freq	factor	Populat	by pop
Geelong	61	1.01	31	37	30	31	0.0	0.0	50.8	0.0	45.7	37	0	0	1.46	160,991	1.46
Colac	130	2.10	3.5	290	70	59	38.4	0.0	0.0	7.3	45.6	145	50	25	1.82	10,857	
Warrnambool	205	3.25	3	346	127	78	0.0	0.0	0.0	38.0	56.9	173	50	25	1.96	28,150	1.92
Bacch Marsh	50	0.50	22.5	44	21	29	0.0	0.0	40.0	0.0	36.0	44	0	0	1.36	13,261	
Ballarat	83	1.23	18	55	49	34	0.0	0.0	41.4	0.0	37.3	55	0	0	1.37	78,221	1.37
Ararat	169	2.49	6	118	94	74	15.3	0.0	0.0	28.8	56.9	118	0	0	1.57	7,169	1.57
Maryborough	155	2.35	6	160	78	77	27.2	0.0	0.0	22.6	58.4	120	25	10	1.74	7,692	1.74
Sunbury	39	0.39	24.5	41	16	23	0.0	0.0	23.5	0.0	21.1	41	0	0	1.21	29,566	
Castlemaine	92	1.32	18.5	54	51	41	0.0	0.0	44.5	0.0	40.0	54	0	0	1.40	7,248	
Bendigo	116	1.56	18.5	54	66	50	0.0	0.0	43.3	0.0	39.0	54	0	0	1.39	81,939	1.35
Echuca	214	3.34	7	106	110	104	4.9	0.0	0.0	43.9	70.3	106	0	0	1.70	12,358	1.70
Swan Hill	240	4.00	4	163	156	84	0.0	0.0	0.0	35.0	52.5	122	25	10	1.68	9,684	1.68
Warragul	96	1.36	17.5	54	56	41	0.0	0.0	42.2	0.0	38.0	54	0	0	1.38	11,498	
Traralgon	138	2.18	17.5	54	79	59	29.8	0.0	0.0	12.8	46.0	54	0	0	1.46	21,960	1.43
Sale	180	3.00	4	227	103	77	9.4	0.0	0.0	33.3	58.5	114	50	25	1.98	13,336	
Bairnsdale	226	3.46	3	340	137	89	0.0	0.0	0.0	39.3	58.9	170	50	25	1.99	11,282	1.98
Wallan	45	0.45	16.5	60	19	26	0.0	0.0	33.1	0.0	29.8	60	0	0	1.30	5,410	
Seymour	85	1.25	20	49	41	44	0.0	0.0	51.9	0.0	46.7	49	0	0	1.47	6,063	1.39
Shepparton	159	2.39	5	148	82	77	23.7	0.0	0.0	24.5	58.2	111	25	10	1.74	38,773	1.74
Benalla	148	2.28	6	156	88	59	21.4	0.0	0.0	18.6	47.2	117	25	10	1.62	9,129	
Wangaratta	175	2.55	6	156	108	67	7.0	0.0	0.0	31.4	53.4	117	25	10	1.69	16,845	
Wodonga	232	3.52	4	216	142	90	0.0	0.0	0.0	38.8	58.2	108	50	25	1.98	29,710	1.83

To account for the travelling time gains in the demand calculation (for which demand elasticities vary according to three time intervals) it is necessary to divide the travel time gains into lower and upper bound values within the respective time intervals. The time gain is separated into upper and lower bound values (as a percentage of original travel time) based on its proportion of each time interval and then sum-multiplied by the demand elasticities for each interval. Only two intervals are used for the travel times above: 31-120 minutes (-0.9) and 121-240 minutes (-1.5). This step is performed in the four “LB/UB” percent travel decrease columns. Where the travel time gain occurs in only one time interval, it is attributed solely to the upper bound (UB) value.

Passenger growth factors by demand elasticities

To/from Melbourne		Maximum line speeds								
Inner line	From/to	160*	200			250			250+	
Geelong	Melbourne	1.18*	1.39			1.46			1.46	
Ballarat	Melbourne	1.20*	1.30			1.37			1.44	
Bendigo	Melbourne	1.21*	1.29			1.35			1.40	
Seymour	Melbourne	1.15*	1.35			1.39			1.42	
Traralgon	Melbourne	1.14*	1.37			1.43			1.49	
Outer line	From/to	160	Now	160	200	Now	160	250	160	250+
Warrnambool	Melbourne	1.75	1.51	1.88	1.94	1.55	1.92	2.04	1.96	2.12
Ararat	Melbourne	1.48	1.38	1.53	1.55	1.44	1.57	1.62	1.61	1.68
Maryborough	Melbourne	1.64	1.44	1.69	1.71	1.50	1.74	1.78	1.79	1.84
Echuca	Melbourne	1.58	1.42	1.66	1.67	1.49	1.70	1.74	1.74	1.80
Swan Hill	Melbourne	1.53	1.33	1.61	1.66	1.36	1.68	1.80	1.74	1.93
Bairnsdale	Melbourne	1.61	1.71	1.91	1.94	1.80	1.98	2.04	2.05	2.13
Shepparton	Melbourne	1.56	1.50	1.70	1.72	1.54	1.74	1.79	1.78	1.86
Albury-Wodonga	Melbourne	1.60	1.58	1.79	1.83	1.63	1.83	1.95	1.87	2.03

To/from regional centres		Max line speed			
Outer line	From/to	160	200	250	250+
Warrnambool	Geelong	1.73	1.79	1.88	1.95
Ararat	Ballarat	1.42	1.46	1.52	1.57
Maryborough	Ballarat	1.68	1.68	1.68	1.68
Echuca	Bendigo	1.50	1.53	1.58	1.62
Swan Hill	Bendigo	1.72	1.77	1.84	1.90
Bairnsdale	Traralgon	1.60	1.63	1.67	1.71
Shepparton	Seymour	1.54	1.58	1.65	1.69
Albury-Wodonga	Seymour	1.56	1.62	1.71	1.80

Passenger growth factors with higher travel time elasticities for one-hour trips

Inner line	160*		200		200		200		250		250		250		250+	
Outer line	160		Current		160		200		Current		160		250		250+	
Service	Time	Factor	Time	Factor	Time	Factor	Time	Factor	Time	Factor	Time	Factor	Time	Factor	Time	Factor
Geelong	0.49	1.39	0.34	1.87	0.34	1.87	0.34	1.87	0.30	2.02	0.30	2.02	0.30	2.02	0.26	2.02
Colac	1.29	1.98	1.41	1.75	1.15	2.26	1.12	2.32	1.37	1.83	1.10	2.35	1.02	2.50	0.53	2.68
Warrnambool	2.26	1.79	2.58	1.49	2.12	1.92	2.04	1.99	2.54	1.54	2.07	1.96	1.48	2.18	1.32	2.36
Bacch Marsh	0.38	1.48	0.24	1.80	0.24	1.80	0.24	1.80	0.21	1.80	0.21	1.80	0.21	1.80	0.18	1.80
Ballarat	1.05	1.44	0.56	1.65	0.56	1.65	0.56	1.65	0.49	1.83	0.49	1.83	0.49	1.83	0.42	2.00
Ararat	1.51	1.54	2.06	1.38	1.42	1.65	1.38	1.69	1.59	1.45	1.34	1.74	1.25	1.85	1.13	1.99
Maryborough	1.34	1.84	2.03	1.44	1.25	1.96	1.23	2.00	1.56	1.53	1.18	2.07	1.12	2.15	1.02	2.30
Sunbury	0.32	1.37	0.18	1.47	0.18	1.47	0.18	1.47	0.16	1.47	0.16	1.47	0.16	1.47	0.14	1.47
Castlemaine	1.07	1.54	0.59	1.72	0.59	1.72	0.59	1.72	0.51	1.89	0.51	1.89	0.51	1.89	0.44	2.05
Bendigo	1.27	1.50	1.16	1.69	1.16	1.69	1.16	1.69	1.06	1.87	1.06	1.87	1.06	1.87	0.56	2.03
Echuca	2.11	1.58	2.34	1.42	1.60	1.66	1.56	1.69	2.24	1.49	1.50	1.76	1.41	1.84	1.26	1.97
Swan Hill	2.58	1.53	3.26	1.30	2.46	1.61	2.39	1.66	3.22	1.36	2.36	1.68	2.18	1.80	1.58	1.94
Warragul	1.25	1.24	1.02	1.71	1.02	1.71	1.02	1.71	0.56	1.84	0.56	1.84	0.56	1.84	0.50	1.97
Traralgon	2.03	1.16	1.29	1.64	1.29	1.64	1.29	1.64	1.19	1.79	1.19	1.79	1.19	1.79	1.10	1.92
Sale	2.27	1.59	2.08	1.79	1.53	1.97	1.51	2.00	1.58	1.90	1.43	2.11	1.38	2.18	1.26	2.34
Bairnsdale	3.01	1.62	3.03	1.61	2.27	1.91	2.23	1.94	2.53	1.69	2.17	1.99	2.06	2.08	1.50	2.24
Wallan	0.38	1.31	0.22	1.66	0.22	1.66	0.22	1.66	0.19	1.66	0.19	1.66	0.19	1.66	0.16	1.66
Seymour	1.10	1.35	0.47	1.89	0.47	1.89	0.47	1.89	0.41	2.04	0.41	2.04	0.41	2.04	0.35	2.18
Shepparton	1.52	1.62	2.01	1.50	1.29	1.94	1.25	1.98	1.55	1.58	1.22	2.03	1.14	2.14	1.03	2.29
Benalla	1.58	1.44	1.42	1.68	1.35	1.78	1.31	1.84	1.36	1.77	1.28	1.88	1.19	2.02	1.08	2.19
Wangaratta	2.17	1.46	2.08	1.54	1.54	1.69	1.49	1.76	2.02	1.60	1.48	1.77	1.34	1.94	1.21	2.11
Wodonga	2.51	1.74	3.07	1.61	2.28	1.93	2.20	1.99	3.01	1.66	2.22	1.98	2.02	2.14	1.44	2.32

Journey times of 'around one hour' are designated greater than 45 minutes and less than 70 minutes; times outside of these limits are shaded in grey.

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Overlay on maps from: OpenStreetMap (2012)
Gröna Tåget Bombardier Regina Train: Bombardier (2012)

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