Travel Demand, Economic Growth and Transport Infrastructure in Rapidly Growing Economies

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Abstract:

South East Asian countries are experiencing rapid growth in income . Inadequate transport infrastructure may well restrict the future economic growth potential of these economies High income growth rates have stimulated large increases in travel demand which in turn have led to congestion and transportation 'bottlenecks' Future economic growth potential may be compromised without adequate infrastructure investment This paper explores the relationships between economic growth, travel demand and transport infrastructure requirements. The high speed rail service proposed for Taiwan is used as a case example to look at some of the problems faced in forecasting demand.

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1. Introduction

Transport (including storage and communications) typically accounts for about 6% of GDP in South East Countries However, national income accounts probably understate transport's importance; transport both enables economic growth and is itself derived from economic growth South East Asian countries are investing heavily in their transport infrastructure During the 1980s, Peninsular Malaysia for example increased its road network from 29,000 kms to 64,000 kms - an average annual rate of 8% Despite big investment programs, transport infrastructure is still seen as a bottleneck which could significantly restrict the growth potential of South East Asia

Currently, rapid income growth rates are being experienced in South East Asia Table 1 presents population, income and transport statistics for a selection of South East countries Malaysia's population grew at 2 4% between 1982 and 1992; Average incomes grew by 9 1% over the same period in South Korea and cars grew by a staggering 27% pa

Table 1
Percentage Annual Change in Population, Income, Cars and Freight Vehicles ('82-'92)

Country	Population	Income Per Capita	Cars	Freight Vehicles
Australia	1.6	2.7	1.9	11.9
Hongkong	0	5.6	-.5	7.7
Indonesia	2.0	n.a.	10.3	12.3
Malaysia	2.4	5.8	7.6	3.0
Philippines	1.6	1.4	-1.1	6.9
Singapore	1.1	n.a.	5.8	3.3
South Korea	0.6	9.1	27.3	18.1
Taiwan	1.1	9.7	18.0	10.8
Thailand	1.5	7.3	20.9	.15

Source: Far Eastern Economic Review 1993 and 1983

Transport demand as measured by the stock of cars and freight vehicles is significantly out pacing the growth in population and average income The problems of such rapid growth in transport demand are twofold: firstly transport demand is outstripping infrastructure supply resulting in increased congestion and time delays; and secondly, existing infrastructure is deteriorating as a result of rising demand and inadequate maintenance. In Indonesia for example, the rail services date back to the turn of the century and have been largely left to deteriorate since WWII, and, of the 266,326 kms of road, 99,845 kms (38%) are in a bad or very bad condition, EIU (1991)

Inadequate transport infrastructure will restrict the future economic growth of these economies It is also apparent that although economic growth has largely stemmed from the private sector and market economics, transport infrastructure needs to be centrally planned The necessary projects are on a big scale, are disruptive and consume large areas of land Project benefits and costs are better evaluated on a social rather than private basis and the risk and long time horizons necessitate government or aid financing

This paper explores the relationship between economic growth, travel demand and transport infrastructure requirements Section 2 looks at the relationship between income, travel demand and transport infrastructure using a simple model Sections 3 and 4 use the high speed rail service proposed for Taiwan as an example of the need for and effect of large scale transport infrastructure investments

2. Relationship Between Income, Travel Demand and Infrastructure

Income, travel demand and transport infrastructure are interlinked Travel is a derived demand with income a key demand determinant Many econometric studies have been undertaken to measure the effect of economic growth on travel demand although most have been in developed countries (section 4 presents parameters estimated for Taiwan) Economic growth itself is influenced by a multitude of factors; the cost of travel (passenger and freight) is one influencing factor. Transport infrastructure influences the cost of travel New roads and railways reduce the cost of travel by providing quicker, more direct route and thereby open up areas to economic development Additional infrastructure capacity relieves transport bottlenecks and makes transportation more reliable and comfortable Unfortunately, although the link between infrastructure and economic development is clear, few empirical studies have been able to quantify the relationship

Equations 1 to 3 below present a simple model of travel demand, average income and transport infrastructure provision Travel demand is a function of population, income and the generalised cost of travel Average income is a function of the generalised cost of travel and other non transport related factors The generalised cost of travel is a function of travel demand and infrastructure capacity The model is instantaneous:- no allowance is made for time delay between infrastructure investment and capacity availability Nor is there a feedback loop between infrastructure cost and economic growth; clearly investment in transport infrastructure has an opportunity cost of reduced resources available for other sectors of the economy

$$Q = \beta_o P^{\beta p} Y^{\beta y} G^{\beta g} \quad (1)$$

$$Y = \alpha_o Z^{\alpha z} G^{\alpha g} \quad (2)$$

$$G = \delta_o Q^{\delta q} C^{\delta c} \quad (3)$$

Q = Travel Demand (trips)

P = Population

Y = Average Income

G = Generalised Cost of Travel

Z = Non Transport Factors

C = Transport Infrastructure

βx = travel demand parameter

αx = average income parameter

δx = travel cost parameter

By respecifying the model in ratio form ((Xt+1)/Xt), the constant terms drop out leaving the model to address changes rather than absolute amounts By inserting values for the parameters (which are also elasticities by virtue of the log-linear form) it is possible to look at how income, travel demand and transport infrastructure interact

The key property of the simple model is *simultaneity*: increasing income levels increase travel demand which in turn increases travel cost Increased travel cost in turn reduces productive efficiency Average incomes are then likely to fall below their potential level which will in turn reduces travel demand An equilibrium solution may be reached however so long as the parameter values are of reasonable magnitude

Table 2 presents the effect of alternative assumptions regarding (i) economic growth, (ii) the level of transport infrastructure and (iii) the underlying parameter values The model was evaluated over twenty years

Table 2
Sensitivity of Income and Travel Demand to Alternative Assumptions

	Model Run												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Annual Growth Rates (% pa):													
Population (P)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3	1.5	1.5	1.5
Income (Z)	8	8	8	8	8	8	8	8	4	8	8	8	8
Infrastructure (C)	0	0	0	0	0	8	16	8	2	8	0	0	4
Parameter Values:													
βp	1	1	1	1	1	1	1	1	1	1	1	1	1
βy	.8	.8	.8	.8	.8	.8	.8	1.6	.8	.8	1.6	.8	.8
βg	-1	-1	-1	-2	-1	-1	-1	-1	-1	-1	-2	0	-1
αz	1	1	1	1	1	1	1	1	1	1	1	1	1
αg	0	-.2	-.4	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2
δq	.5	.5	.5	.5	1	.5	.5	.5	.5	.5	.5	.5	.5
δc	-.5	-.5	-.5	-.5	-1	-.5	-.5	-.5	-.5	-.5	-.5	-.5	-.5
Ratio Change After Twenty Years (t_{20}/t_1) t_1=100:													
Travel Demand	461	412	374	412	374	462	513	1336	243	606	1080	1581	437
Population	135	135	135	135	135	135	135	135	135	181	135	135	135
Income	466	405	358	405	358	467	533	420	209	454	367	466	435
Travel Cost	215	203	193	203	374	100	51	169	128	114	329	100	141
Infrastructure	100	100	100	100	100	466	1946	466	149	466	100	100	219

The model runs assume an annual income growth rate of 8% due to non transport factors excepting model 9 (4%) Population growth rates of 1 5% pa were assumed except model 10 (3%) Transport infrastructure growth rates of 0% (models 1 to 5, 11 and 12), equal to the growth in income (models 6, 8 and 10), half the income growth (model 9) and double the income growth (model 9) were tested

A unitary population elasticity (βp=1) was assumed throughout A central income elasticity (βy) of 0 8 was assumed with a variant of 1 6 (models 8 and 11) A unitary travel cost elasticity (βc) was assumed excepting models (4 and 11) for which a value of -2 was assumed and model 12 (zero value) The elasticity of income with respect to non transport factors (αz) was set at one and the elasticity of income with respect to travel cost (αg) was set at -0 2 excepting model 1 (zero) and model 3 (0 4) Values of 0 5 and -0 5 were set for the travel cost with respect to travel demand (δq) and infrastructure capacity (δc) respectively excepting model 5 for which unitary values were set

With no increase in infrastructure capacity, average income is constrained below its realisable potential The reduction is greater the greater the sensitivity of income to travel cost (αg) and/or travel cost to travel demand and capacity (δq and δc) In model 3, (αg=-0 4) and model 5 (δq = 1 and δc = -1) income growth is constrained to around three quarters of its potential Model 1 is unconstrained by setting (αg=0) so that despite zero infrastructure investment, there is no impact on income Models 2 and 4 show that the value of βc has net impact

In Model 1, travel demand is projected to increase by 4 6 times its base level; an increase in trip rate of 3 4 times Travel costs are projected to slightly more than double with no infrastructure investment

Investing in infrastructure at the same rate as potential income growth imposes no constraint (model 6) Greater growth can be achieved by investing more in infrastructure; in model 7 with infrastructure increased at twice income growth (Z) realised income grows to 14% above model 6 However the increase in infrastructure is over four times that of model 6 Travel costs halve and travel demand rises by over five times.

With a high income elasticity of demand, model 8 (βy = 1 6), travel demand is forecast to rise 13 fold over twenty years with an 8% increase in income (Z) and infrastructure. Travel costs rise by 1 7 times and realised income increases by 4 2 times

Model 9 shows a lower growth scenario Income growth (Z) is 4% double the infrastructure growth Travel demand increases 2.4 times and travel costs increase by 28%

Model 10 shows the effect of a higher population growth of 3% thirty percent more trips are made compared to model 6, with travel costs 11% higher and realised income 3% lower

Model 11 has high income and travel cost demand elasticities and compares with model 2 Travel demand rises nearly eleven fold whilst travel costs rise threefold despite no infrastructure investment The model shows the importance of the income elasticity relative to the travel cost elasticity

Model 13 is perhaps most typical Infrastructure investment is lagging (4%) behind the growth in income (Z=8%) With the given parameters, realised income will be constrained 7% under its potential Travel demand will however rise four fold and travel costs increase by 14% despite the doubling of transport capacity

3. Case Example: Taiwan High Speed Rail - Overview

Taiwan illustrates the infrastructure problems of high growth economies. Economic activity is increasing rapidly and despite significant infrastructure investment, transport bottlenecks are constraining development A high speed rail service is planned to provide a high capacity high quality service promoting economic integration and growth Section 3 describes the project and section 4 presents some demand parameters

Socio-Economic Description

Taiwan is a pear shaped island about 370 kms long and 150 kms wide (at its widest point) In 1989, Taiwan's population passed twenty million Compared to New Zealand, Taiwan's population is seven times greater and inhabits an area one seventh the size; its population density is therefore about 49 times that of New Zealand

Much of Central and Eastern Taiwan is mountainous with nearly nineteen out of twenty people living on the western coast Four metropolitan areas: Taipei in the north, Taichung, Chiayi and Kaohsiung/Tainan in the south accommodate most of the population The West Coast has an area of 25,600 square kilometres and has an average population density of 750 persons per square kilometre In the three main cities: Taipei, Taichung and Kaohsiung, the densities are much higher still: 10,000, 4,600 and 9,000 respectively

Gross Domestic Product reached NT$4,222 billion in 1990 (US$ 157 billion equivalent) of which the west corridor accounted for all but two percent GDP per capita was US$ 7,700 During the 1980s, GDP per capita grew at just under 10%. Private car ownership grew at annual rate of 18% so that by 1990 there were 5 5 times as many cars as in 1980

Over the next twenty years, the Taiwan economy is projected to continue to grow rapidly Average household income is forecast to double by 2011 and private car ownership is forecast to quadruple Twice as many trips per day are forecast between the main west coast cities than at present By 2011, 710,000 trips per day are forecast between the main cities on the west coast corridor

Table 3
Socio-Economic Profile of Taiwan

	1980	1985	1990
Population (1000s)	17,805	19,258	20,359
Income Per Capita (NT$)	77,575	119,272	195,905
Cars / Thousand Population	23.8	47.5	114.4

Current Transport Services

In 1978, the North-South Freeway was opened Since then, the level of transport infrastructure has not kept pace with the growth in size of the Taiwan economy Highway construction grew by only 15% over the 1980s Congestion is becoming a serious problem; it now takes about four hours to travel between Taipei and Kaoishung, a distance of around 350 kms Travel times are also unreliable as a result of traffic variability A Second freeway and a Coast Expressway (to be completed before 2011) are planned but the expected traffic growth is such that both highways will be saturated on the day of opening A range of bus services are provided ranging from State scheduled express services to "Wild Chicken" services which are largely unregulated and unscheduled Domestic air services are expanding but will be ultimately limited by the short length of the corridor

Rail offers the potential to bridge the infrastructure gap: rail can offer fast, predictable and high capacity services Over recent years however, rail traffic volumes in Taiwan have remained static despite population and economic growth The existing rail services (TRA) suffer from their narrow gauge and poor alignment Speeds cannot be raised much above the current 120kph without incurring significant costs

Proposed High Speed Rail

The proposed solution to Taiwan's growing inter-city transportation problems is a new High Speed Rail (HSR) service (see Figure 1) The HSR would reduce the North-South travel time from four hours to 1 5 hours and bring the whole of West Taiwan together as a *"single daily-activity boundary* (see Figure 2).

The HSR is intended to integrate with the existing TRA service (which will concentrate on local services) and Mass Rapid Transport services planned for Taipei (also Taoyuan and Hsinchu), Taichung and Kaohsiung (also Tainan)

HSR Construction Details

The design speed for the HSR is 350 kph and operation speed is 350-300 kph The total line length: Taipei - Kaohsiung is 345 kilometres. Five intermediate stations are also planned: Taoyuan, Hsinchu, Taichung, Chiayi and Tainan Sixty percent of the rail length will be viaducts and bridges - to enable surface intersections and the land underneath to be utilised. Around twenty four kilometres of tunnel will be needed in the more hilly North and Central areas and a 11 6km cut and cover section through Taipei City

Two rolling systems were evaluated: steel wheel-on-rail and magnetic levitation. Steel wheel was selected because of its proven nature. Japanese Shinkansen, French TGV and German ICE have been short listed as tenderers. The tender specifications are: seat capacity per trainset: 800 -1,000 passengers; service speed: 250 - 300 km/hr; traction power supply: 25kV in single phase Rolling stock, signalling and catenary will be tendered as a package because of their interface and critical relation with the rolling stock.

Total construction costs are estimated at NT$ 426 6 billion (1991) or US$ 17 billion Civil works will account for 55% of the costs; land acquisition and demolition 18%; rolling stock 16% and stations/yarding 11%

HSR Patronage and Revenue

A preliminary demand analysis has been undertaken by Sofrerail They forecast a daily ridership in 2011 of 187,000 trips with Taipei, Taichung and Kaohsiung accounting for nearly three quarters of patronage Optimal revenue is forecast at a fare of NT$ 3 per passenger kilometre (approximately NT$ 990 at 1991 prices for Taipei-Kaohsiung) In 2011, forecast revenues are NT$36 2 billion. The project is intended to be 45% self-financing ie. NT$ 192.4 billion of the 426 6 billion of construction costs. The remainder will be financed by government.

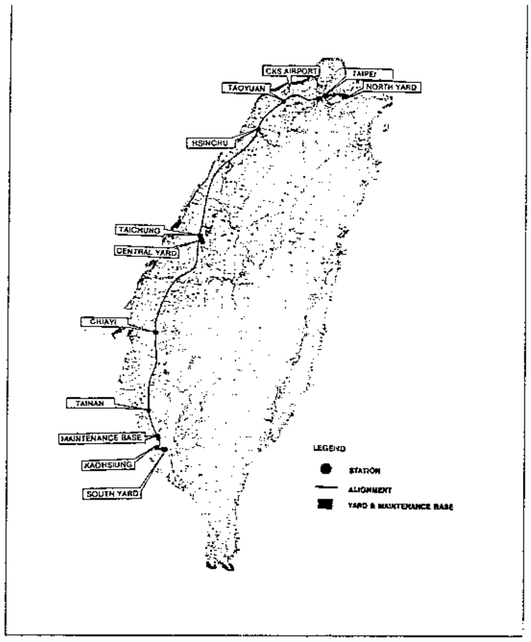

Figure 1
Taiwan High Speed Rail System

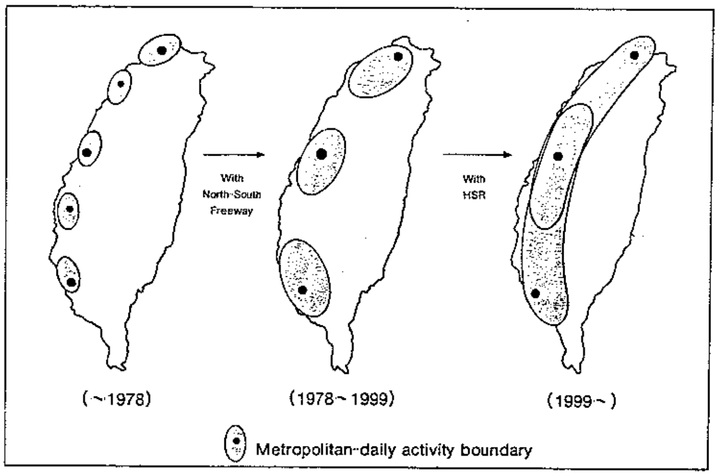

Figure 2
Regional Development with Transportation Development in Taiwan
Source PEOHSR 1992

4. Demand Forecasting Methodology

In 1992, the Provisional Office of High Speed Rail began detailed demand modelling The first phase involved a preliminary analysis of the three main flows: Taipei to Taichung; Tapei to Kaoshuing and Taichung to Kaoishung. The patronage for the High Speed Rail (HSR) was forecast in components:

It = B Xt St (It+Dt)

where:

It = Trips by HSR in year t
B = Base Year
Xt = Market growth due to population, income and car ownership
St = HSR proportion of total market, ie diversion from air, car, bus and TRA
(It+Dt)= Induced demand (equal to new trips plus diverted trips from other areas)

Three scenarios were modelled:

- Base 1989: Replication of the existing situation without HSR.
- *"Business as Usual* which included market growth attributable to population and income but was *capacity restrained* by available road infrastructure (by including a feedback loop of road time on demand).
- *"With HSR"* which allowed for constrained market growth, HSR service level and bus, air and TRA competitive response (eg reduced bus fares) or equilibrium response (reduction in bus service interval)

Future road congestion also disadvantaged the scheduled passenger transport modes (bus, rail and air) through increased road access times (weighted double line-haul times) as well as car and express bus highway times

Two models were estimated: (i) a market share model and (ii), a total market model. The model structure was recursive; the market share model *results* fed into the total demand model

- **Market Share Model**

The estimated market share model adopted a logit form in which the share of an existing mode (air, bus, car or TRA) was a function of its relative service level For air the estimation equation was:

$$S_{air} = \frac{Exp(bm.GT_{air})}{Exp(bm\ GT_{air})+Exp(bm\ GT_{bus})+Exp(bm\ GT_{car})+Exp(bm\ GT_{TRA})}$$

where: S denotes probability of travelling; GT = generalised time; bm = parameter to be estimated

- **Total Market Model:**

The Total Demand model adopted a functional form which allowed the elasticity with respect to generalised time (GT) to increase with GT:

ln Iij = bo + b1 (1/bm (lsGI)) + b2 (ln(Pi Yi Pj Yj)) + b3 (ln (PiCi+PjCj)/(Pi+Pj))
where: Iij = total trips (business or leisure) between i and j
Pi Yi Pj Yj= the product of the gross zonal domestic product (ie population times average per capita income of zone i times that of zone j)
(PiCi+PjCj)/(Pi+Pj) = the average cars per capita of zones i and j
bo, b1, b2 and b3 are parameters to be estimated
(1/bm) lsGI = the log sum of the expected maximum utilities of the individual travel modes times by the mode share GT parameter (expresses the variable in time units)

As an example, for the car available sub market, generalised time for travellers with a car available was equal to:

lsGIca =(1/bm) ln(exp(GI airca)+exp(GI busca)+exp(GI carca)+exp(GI IRAca))

However, lsGI needed to be trip weighted to take account of the proportion of each market (business and non business) with a car available:

lsGI = (lsGIca Ica + lsGInca Inca)/(Ica+Inca)

Crucial to the forecasts were values of time which influence mode choice and total travel demand A non business value of time of $NI 70 and a business value of around $NI 170 (base values varied by mode) were used for 1990 For forecast years, the base values were inflated according to the rise in average income Population, income and car ownership determined the size of the total market and also influenced market share Income and car ownership move in tandem; high growth rates in income induce greater car ownership Population and income are also likely to be correlated although less strongly High population growth also acts to lower average income, other things being equal

The total effect on HSR ridership need not be straightforward Income not only induces greater trip making but also raises peoples' value of time shifting preferences in favour of faster modes Car ownership also induces greater trip making but will also lead to greater use of car and a shift away from scheduled travel modes Changes to the increase in road time were also evaluated Clearly, road time and the other socio-economic scenarios will tend to be negatively correlated The estimated generalised time parameters were highly significant; |t| values were well in excess of two (see Table 4) Goodness of fit was highest for the car available models The parameters were of reasonable size (values ranging from 0 005 to 0 1 are typical n inter-urban mode share modelling) The model was estimated without mode specific constants The market shares were found to be most sensitive in the "car available market".

Table 4
Market Share Parameter Estimates

Purpose	Car Availability	Mean Estimate	|t| value	Rho bar Squared
Business	Car Available	-0.0456	7.2	0.71
Business	No Car Available	-0.0056	4.0	0.11
Leisure	Car Available	-0.0214	6.9	0.42
Leisure	No Car Available	-0.0082	3.7	0.27

A good fit was achieved for both the business and leisure models total travel demand models (see Table 5) The parameters were significant, of correct sign and of reasonable magnitude Travel demand was estimated to be slightly inelastic with respect to a change in the total income of one zone (population times average income). Business trips were predicted to increase by 8 4% from a 10% rise in average income of one zone However if all four terms (population of zones i and j and average incomes of zones i and j) rose by 10%, the predicted increase in trips was 36%

Table 5
Total Demand Parameter Estimates

	Business		Leisure	
	Mean	|t|	Mean	|t|
Constant	-30.45	5.5	-35.20	8.35
Generalised Time	-0.00823	10.9	-0.0045	12.96
Log (Total Income Product)	0.84	8.3	0.94	12.70
Log (Car Ownership Per Capita)	1.24	3.5	1.23	4.79
Adjusted R Squared	0.70		0.82	
Std Error of estimate	0.86		0.62	
Degrees of Freedom	95		95	

Total market demand was predicted to be elastic with respect to changes in car ownership The form of the estimation equation meant that the generalised time elasticity rose with generalised time An alternative multiplicative model (double log) was fitted and the resultant elasticities were -2 13 and -1.69 for business and non business respectively That is, a 10% reduction in generalised time across all modes induced a 21 3% increase in business trips and a 16 9% in leisure trips.

- **Forecasting**

An *"Incremental approach"* was used to forecast both total demand and modal shares Model forecasts were made on the existing situation Forecasting *changes* removed any errors in forecasting the base

Forecasting Induced demand was undertaken in two parts A *"With HSR"* forecast was made (with all changes made) and a *Without HSR* (all other changes apart from HSR made) Any increase in the total market between the *"With"* and *"Without"* forecasts was then assigned to the HSR Highway road times were assumed to increase by 0 75% pa and urban road times by 1.15% pa *With the HSR* and by 0 7% and 1 1% *Without the HSR* Additional assumptions were a constant car occupancy and constant real fares and petrol costs etc

To test the reasonableness of the forecasts variations in annual growth rates in key variables were tested: population +/- 20%; income +/- 30%; car ownership +/- 30%; and road time +/- 30% The effect on patronage was measured in terms of elasticities.

Table 6
Sensitivity of HSR Ridership to Changes in Key Variables
Estimated Elasticities

	1999		2011	
	*1.3	/1.3	*1.3	/1.3
Population(1)	.08	.07	0.17	0.14
Income	2.31	1.70	5.3	3.54
Car Ownership	.19	.17	0.14	0.17
Road Time	-0.14	-0.10	-0.39	-0.29

Notes: (1) Population times 1 2 and divided by 1 2 respectively (not 1 3)
Elasticities refer to total passenger kilometres ie the three flows weighted by distance
constant elasticities calculated of the form: e = ln(Q2/Q1)/ln(X2/X1)

The *"assumed"* income growth rate has a major significance on the ridership forecasts. Income has three effects: firstly, it directly increases the overall propensity to travel and secondly, it raises the value of time which in turn indirectly increases the "modelled" desire to travel (by reducing the cost component of the total generalised time measure) and thirdly favours HSR over slower ground transport modes. The elasticities imply that raising the income growth rate by 10% between 1989 and 1999 would lead to a 23% growth in HSR trips (an elasticity of 2 31). If this was compounded up to 2011, a 53% increase in HSR trips would be predicted. The elasticities are non symmetrical however: reducing the annual growth rate by 10% leads to a 17% reduction in 1999 HSR trips and a 35% reduction in 2011

The forecasts were far less sensitive to population growth (which is also more predictable although variations within the West Coast Corridor could be of significance). Total demand was elastic with respect to car ownership (greater than one) but a counterbalancing effect of increased use of car reduced its overall effect fro HSR

The elasticity with respect to road time was negative. Increasing the rate of increase in road time (to reflect congestion) reduced HSR ridership. This resulted from: (i) a reduced total market and (ii) increased access time to the HSR stations more than offsetting (iii) the improvement in rail's competitive position *vis a vis* car.
Elasticities were also computed to gauge the response to HSR fare and service level. Elasticities for a doubling and halving of fare, journey time (IVT) and service level were calculated for 1999 and 2011. The elasticities were found to change over the two time periods as a result of increased incomes pushing up values of time and greater car availability

The elasticities were of correct negative sign and were of reasonable magnitude. Demand was forecast to be sensitive to improved service but average incomes are such that fares need to be priced competitively

Table 7
Estimated Elasticities for HSR Ridership with respect to
to changes in Fare, HSR Journey Time and Service Interval

	1999		2011	
	Doubling	Halving	Doubling	Halving
Total Market				
Fare	-1.69	-2.04	-1.74	-1.66
In vehicle Time	-0.63	-0.42	-0.72	-0.37
Service Interval	-0.07	-0.04	-0.06	-0.03
Business				
Fare	-2.23	-1.50	-2.28	-0.89
In vehicle Time	-1.28	-0.76	-1.65	-0.53
Service Interval	-0.14	-0.07	-0.10	-0.05
Leisure				
Fare	-1.52	-2.21	-1.61	-1.84
In vehicle Time	-0.43	-0.26	-0.52	-0.32
Service Interval	-0.05	-0.02	-0.05	-0.02

Notes: In vehicle time is HSR journey time excluding access and egress
Service Interval is minutes between HSR departures
Elasticities referred to total passenger kilometres ie. the three flows weighted by distance
constant elasticities calculated: $e = \ln(Q2/Q1)/\ln(X2/X1)$

The in vehicle time elasticity was around -0.6 rising to -0.7 in 2011 as increasing values of time pushed up the importance of travel times, absolutely and relatively. In 1999, the in vehicle time elasticity accounted for 37% of the fare elasticity - a result of relatively low values of time especially in the leisure market whilst in 2011, the *share* was 41%.

The response to changes in service interval was weak with elasticities ranging from -0.04 to -0.1. This resulted from a high base frequency (every 15 minutes) and an assumption of a minute of service interval being worth 0.4 minutes of in vehicle time. Providing extra services had very little uplifting effect on ridership. The elasticity measures did however show a differential effect to (i) improvements and (ii) reductions in frequency. A greater percentage loss was predicted for a doubling of service interval (reduction in frequency) than for a halving.

The elasticities suggest that revenue (especially on Taipei-Kaoishung) could be increased by lowering fares. A 10% reduction would increase revenue by 7%. However, for net revenue to increase by a similar margin, cost would not have to increase and no demand would have to be "crowded off" by a lack of capacity. If capacity has to be increased by more than 7%, and assuming costs rise proportionally with output (constant costs), the net revenue position would deteriorate (with allowance made for a rise in demand stimulated by the capacity increase)

6. Conclusions

Transport infrastructure enables economic growth and is itself derived from economic growth. South East Asian countries are investing heavily in their transport infrastructure to cope with double digit growth rates in car ownership and travel demand. Travel demand appears to be highly elastic with respect to income. However, without sufficient investment in transport, travel costs will increase and dampen demand and economic activity

Congestion is a very inefficient mechanism for restraining demand. In the rapidly growing of South East Asia, travel demand is increasingly capacity restrained. The resultant bottlenecks are now impinging on economic activity and income growth

Taiwan, sees high speed rail as a solution to future congestion problems. Travel times would be significantly reduced bringing the whole of West Taiwan together as a *"single daily-activity boundary"*. When integrated with the existing rail services and Mass Rapid Transport services, rail will provide a high capacity, high quality service which will both promote and enable continued economic growth

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