Is rail traffic useful or necessary for regional development?

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Abstract

In the language of financiers the ends of regional development may be described by high prosperity and low poverty. Showing that installing, upgrading or extending rail infrastructure and transport in a region and between neighbouring regions will be accepted by freight and passenger traffic which will help to develop the economic base of the regions concerned may be a strong argument for railway or urban transport projects. The article suggests a simplified methodological toolkit to assess impacts of transport infrastructure projects on regional development, suitable for developing countries, and presents some first preliminary results for Vietnam derived from linear regression models for regions under development, applied to two railways development scenarios. However, both the methodology as well as its application is subject to further development in the ongoing study.

Keywords: Vietnam, regional development, accessibility, poverty, simulation models, railway infrastructure improvements.

1 Introduction

If environmental friendly, low-energy-consumption and low-air-pollution transportation systems are necessary to provide sustainable mobility, and rail traffic is such a transportation system, and rail traffic is used as part of the system, then rail traffic is necessary for regional development.

If passenger traffic and freight traffic are required for regional development, and rail traffic is supposed to be part of the regional transportation system, then rail traffic is at least useful to regional development. We shall try to find arguments at least for the useful-thesis.
South-East Asian railway systems, although all in metre gauge, are divided into different networks: Myanma (Birma) and Cambodia have isolated national networks. Laos has no railway at all. Thailand, Malaysia and Singapore are linked together. Vietnam and China are linked by two international lines using an interesting handling of their differing gauges.

These different railways are supposed to be linked soon through the Trans-Asian-Railway programme to a common rail network even including Cambodia. The question is, if all these national economies then connected and if all regions e.g. of Vietnam will gain by the additional traffic. Or will there be losers as well?

It seems that especially Vietnam is carefully studying such questions, in particular because private automobile motorisation is relatively low, so that after improvements of the railway system there are chances for the Vietnamese Railway Corporation to play a fundamental role in mobility.

This paper presents first preliminary results of an ongoing study on accessibility patterns in Vietnam, and on how to improve the railway system in order to make the railway system fit to meet the future needs of Vietnam.

2 Studying socio-economic impacts of rail traffic in Vietnam

Vietnam (Figure 1) with its surface of 331,114 km² and population of 76.52 million inhabitants seems to be quite similar to Germany (316,270 km² and 79.2 million inhabitants). But the shape and latitude of the countries differ a lot. Their economies are very different in amount and growth and so are their railway systems.

Figure 1: Socio-economic situation in Vietnam: Population density (left), employment (middle-left), GDP (middle-right) and poverty (right) (Adams [1], Freeman [3], Le [4]).
Vietnam Railways consists of a star network with the center in the capital Hanoi, two international lines to China, two short lines to the northern mining regions, two short lines linking the ports of Haiphong and Halong and one 1726 km long single track main line to Saigon/Ho Chi Minh City (Figure 2, right).

There is a master plan to upgrade this system, reactivate some short lines which for a long time have not been used, reconstruct some branches which were destroyed in the wars, and add some new branches, especially in the South. Two of the new lines will link Vietnam (and China) to Laos and Cambodia and start the planned international network.

Today there are 61 regions in Vietnam, provinces and the cities of Hanoi, Ho Chi Minh, Haiphong and Danang. These 4 cities and 28 provinces are directly linked to the rail network by stations, but 29 provinces are not. About one half of them will become part of the expanded network and get access to the national and international trade.

![Figure 2](image)

Figure 2: Land use, settlement structure and transport infrastructure in Vietnam: Land cover (left), settlement (middle-left), road network (middle-right), railways (right).

3 The idea: toolkit for railway planning

Is rail traffic useful or necessary for regional development? To answer this question a relation between rail traffic and economic development has to be found. The relevant attribute is gross domestic product (GDP), or poverty. Increasing GDP or reducing poverty may mean to develop a region. To study relations between regional development and rail traffic a toolkit of computer aided methods will be applied:

- The regression tool will enable us to test the relations between regional attribute vectors, such as population and employment, and traffic generated or traffic and prosperity.
- The accessibility tool will generate values of passenger and freight weighted mean distance from every region to all other regions.
- The traffic generation tool will generate the amounts of passenger and freight traffic for every region (traffic cell) according to its attributes using the data of accessibility and the regression methods.

4 The regression tool

Regressions not only compare different attributes of entities, e.g. regions or traffic cells, as do correlations, although correlations are required as basic operations in regressions. Regressions can join different attributes into a compound one and regressions calculate coefficients in functions relating input attributes (arguments) to output variables. These coefficients and functions then may be applied to data of different scenarios thus presuming they will behave the same way as the analysed scenario. So What-If questions may be answered and future may be planned.

There exists a broad spectrum of theoretical approaches to explain the impacts of transport infrastructure (investments) on regional development (Bröcker ET AL. [2], Linnecker [5]). Besides others, the classical production function approach models economic activity in a region as a function of production factors (capital \( C \), labour \( L \), land, as being the traditional factors), where in modern approaches infrastructure or accessibilities \( A \) is added as an additional important factor. Thus, the general function to model GDP (forecasts) of region \( r \) can be written as

\[
Q_r = f[C_r, L_r, A_r, R_r]
\]  

(1)

However, since this is an ongoing study, at the time being the analysis is focussing on the relationship between labour, accessibility and GDP. At a later stage, capital and other production factors will also be taken into account.

The question now is whether to combine these factors in an additive or multiplicative way, both having specific (dis-)advantages. The most common form of regression uses linear functions of the sum form:

\[
Y = X_1c_1 + X_2c_2 + \ldots + X_n c_n 
\]  

(2)

Logically the different causes \( Xi * ci \) may well replace each other and are related by the OR operator. The impact \( Y \) will only fail if all causes fail. Combining rail passenger traffic and other passenger traffic to passenger traffic is an example for a linear regression or OR regression, and the sum form is successful as well to calculate the freight traffic as a function of railway freight traffic and other freight traffic. So railway traffic does contribute to the total traffic, both for passengers and for freight, i.e. rail traffic is (at least) useful.

According to the well known logical AND operator there is a regression function of the product form:
Y = X1^c1 * X2^c2 * ... * Xn^cn  \hspace{1cm} (3)

In this case there will be only Y impacts if all causes Xi^ci exist. If rail traffic was related to other traffic and other activities to give GDP we were able to state that rail traffic is necessary for regional development (no rail traffic, no development). But there is GDP in many countries without any railway, e.g. in Laos, and even in Vietnam there are regions without railways but not without GDP. So this assumption does not yield, i.e. rail traffic is not necessary.

But we found other arguments for the impact variable GDP still using the production function approach. We supposed there would be no regional GDP without freight traffic and without passenger traffic and without other activities. As regressions showed positive exponents ci for all three input variables, our assumption was right.

Other applications of the product form regression are the calculations of railway passenger traffic and of railway freight traffic. We found accessibilities for passengers and freight (both discussed in an extra chapter) were suitable causes for the concerned traffics. As passenger accessibility is measured in persons and freight accessibility in GDP, we combined passenger accessibilities with population and freight accessibilities with GDP as well.

Usually arguments and function variables are of different dimensions and so it is usual to apply all combining calculations (e.g. regressions) on dimensionless data. In Richter [6] we found a z-transformation and a $\nu$-transformation to remove dimensions from regression variables. Using product form regression functions we have to reduce potential terms Xi^ci into products ci*ln(Xi) by logarithmation. So we must not use z-transformation which transforms arithmetic mean to 0 and standard deviation to 1 and shifts about one half of the data into the negative range. Instead we use $\nu$-transformation which transforms max to 1 and min to 0 for sum form linear regressions. For the product form regressions we transform max to e and min to 1 and natural logarithm ln() does the rest of the task.

To summarise: The Regression Tool consists of linear sum form regression and different linear transformations. For OR type regressions where the 0 result is obtained only if all arguments disappear the $\nu$-transformation will convert max to 1 and min to 0 and the original linear regression is applied unchanged.

For AND type regressions where the 0 result is obtained if only one argument value disappears the product form regression has to be applied. Here we use another linear transformation to convert max to e and min to 1. Then natural logarithm will reduce the ^ operator to * and the * operator to + and transform all argument values, especially e to 1 and 1 to 0. So everything is ready to apply the original linear regression as well.

5 The accessibility tool

While all the other attributes of a region or a traffic cell are only related to the cell itself, the accessibility tells how much this cell is related to all other cells. The accessibility indicator used in this study is based on the assumption that the attraction of a destination increases with size and declines with distance or travel.
time or cost. Therefore both size and distance of destinations are taken into account. The economic potential of a region is the total of destinations in all regions weighted by a function of distance from the origin region, hence the potential for economic activity at any location is a function of its proximity \( f(c_{ij}) \) to other economic centres and of its economic size \( g(W_j) \) (Schürmann AND Talaat [7]):

\[
A_i = \sum_j g(W_j) f(c_{ij})
\]

where \( W_j \) represents region population (accessibility to population) or GDP (accessibility to GDP). For \( f(c_{ij}) \) we apply the “bell” function \( e^{-(t/t_m/2)^2} \) because of the following reasons:

1. As \( t_m \) is the arithmetic average of \( t \), it is of the same dimension and so we easily get a dimensionless argument \( t/t_m \) for the following operations.
2. General numbers on \( t_m \), the average of \( t \), is often given for a study region. For example, from the 2003 timetables in Vietnam Railways [8] average speeds of 50 km/h for passenger trains and 25 km/h for freight trains were derived. So the average travelling times for passengers resulted in 6.5 hours and for freight in 14 hours and the distance functions \( f(c_{ij}) \) were easily tailored.
3. The “bell” function is steadily defined for all argument values. Especially for the distance \( t=0 \) the result is 1 and then decreases steadily. This means that for the cell \( i \) with no distance to itself there may result a high internal traffic. This internal traffic may easily be omitted if so required.

6 The traffic generation tool

In a final step, the traffic generation tool generates rail passenger and rail freight traffic for the whole year 2003 processing the data [9] for the first 10 months of that year. These data were distributed among the 29 traffic cells connected to Vietnam Railways according to population density and employment.

7 Tools, application and results

For the purpose of this paper, two scenarios have been applied: A base year scenario or status-quo scenario where trains run at travelling speeds of 2003 timetable (i.e. passenger trains run at average speeds of 50 km/h and freight trains run at 25 km/h) and a railways accelerated speed scenario, where passenger trains run at average speeds of 65 km/h and freight trains at 40 km/h. However, it is planned to assess more scenarios in the near future.

Rail passenger and rail freight accessibilities were calculated applying different “bell” functions on Population and GDP. Figure 3 represents the standardised accessibility indicators. In the base scenario (maps on left hand side in Figure 3), both accessibility to population and accessibility to GDP reveal highest accessibility in the northern provinces around the capital city of Hanoi, where the density of the railway network is highest. Following the main railway
line in southern direction, both accessibility indicators decrease. Even Saigon as being the south end of the main railway line only yields population accessibility of one-quarter of the region with the highest accessibility; although Saigon has a relatively high self-potential, but railway connections to its hinterland are lacking. With respect to accessibility to GDP (Figure 3, middle-left), Saigon and its surrounding regions show above-average accessibility.

When looking at changes in accessibility, of course all regions experience increase in accessibility through the acceleration scenario. However, it is more interesting to look who are the relative winners and relative loosers, i.e. to look at the relative changes (maps on the right hand side in Figure 3). With respect to population, highest relative gains through the acceleration scenario will occur in regions north-west of Hanoi, linking Hanoi with China. On the other hand, also regions along the main south line will improve their accessibility significantly; Danang will experience highest increases. Interestingly, all southern provinces of Vietnam including areas around Saigon will not improve their relative position. Somewhat similar patterns will be found when looking at changes of accessibility to GDP. The great agglomerations in the north (Hanoi) and south (Saigon) and their hinterland will experience relative losses, whereas the regions in between will be able to catch up, which clearly gives hints to cohesion effects of a decentralised railway infrastructure supply.

Based on these accessibility patterns, the regression tool found the functions:

\[
\text{Rail\_passenger\_traffic} = (\text{Population}^{0.95} \times \text{Rail\_passenger\_accessibility}^{0.07})
\]

and

\[
\text{Rail\_freight\_traffic} = (\text{GDP}^{0.90} \times \text{Rail\_freight\_accessibility}^{0.08}).
\]
Rail passenger traffic was added to other passenger traffic to get passenger traffic and rail freight traffic was added to other freight traffic to give freight traffic. We applied linear OR type regressions just to show they work no matter whether the cells processed are railways cells or not. The tool found the following functions:

Passenger traffic = (Rail.passenger.traffic*0.11 + Other.passenger.traffic*0.88) and

Freight traffic = (Rail.freight.traffic*0.13 + Other.freight.traffic*0.87).

Finally passenger traffic, freight traffic and other activities were processed by the AND type product regression to get GDP. The tool found the following function:

GDP = (Passenger.traffic^0.17 * Freight.traffic^0.10 * Other.activities^0.76).

The resulting coefficients and exponents found by regression may be interpreted as follows:

There are remarkable influences of accessibilities (7% and 8%) on rail passenger and rail freight traffics. Most of rail passenger and freight traffics (95% and 90%) are influenced by the cell variables population and GDP.

Where cells are linked to Vietnam Railways by stations railway traffic may be about 11% or 13% of total traffic, passengers or freight.

GDP seems to be completely determined by freight traffic (10%), passenger traffic (17%) and other activities (76%).

8 Conclusions

Discussing the modelled GDP figures it can be stated that population density strongly correlates to GDP per area. This may declare a lot about why crowded cities like Saigon-Ho Chi Minh City tend to grow rapidly. Like with gold rushes in history population seems to concentrate where prosperity is concentrated.

This brings time process into focus. If accessibility and thus GDP is improved in regions outside yet in the neighbourhood of such large cities, e.g. applying improved railway transportation systems, there are chances to control or at least slow down agglomeration processes. This is particular important for developing countries, whose automobile motorisation rate is still comparatively low, but who suffer from the growth of their agglomeration centres.

In Hanoi and Ho Chi Minh City Urban Mass Transit systems, i.e. rail passenger transportation systems, are being planned or under construction. Next years Vietnam Railways will reactivate and reconstruct rail links to the neighbouring countries Laos and Cambodia to become part of a common rail transportation system from China to Singapore.

The methodological framework proposed here ought to be applied and tested with more differentiated data, on a more disaggregated system of regions, and of course with more scenarios. It will furthermore be enhanced with additional tools to optimise and to visualise timetables, to calculate demand at a small scale, and to optimise railway track alignments (e.g. avoiding steep segments) and train stop planning. Altogether, this will form a comprehensive set of (easy-to-use) GIS-based tools for railway planning in development countries.
Finally, the sustainability point of view has to be entered into the discussion. Rail transport and especially urban rail transport is supposed to be as environmentally friendly as ferry boats, pedestrians and cyclists. So in the end the questions in our title may be answered this way: *Rail traffic is not only useful to regional development, it is even necessary.*

**References**