Joining GIS-database and timetable simulation to optimise Asian Railways topology and operation

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Abstract

Asian Railways are merging. There are feasibility studies for a unified line from Singapore to Kunming linking Malaysia, Thailand, Cambodia, Vietnam and China. This line may later on become part of the Southern Corridor of the Trans-Asian Railways connecting Europe to Eastern Asia. This new line will induce additional traffic especially on Vietnam Railways, additional and upgraded infrastructure, denser timetables and higher transportation expenses. But it may also mean a chance to improve socio-economic conditions, e.g. establishing a reliable meshed network, introducing higher standards in just-in-time production and fast multi-modal passenger transport. The authors propose a joint approach to combine GIS databases, GIS techniques and timetable simulation tools into a comprehensive toolbox so that different variants of infrastructure and operation may be studied.

Keywords: Vietnam, simulation models, railway infrastructure improvements, timetable optimisation, regional development, accessibility, GIS.

1 Introduction

Transport demand of Asian societies is constantly growing due to the rapid economic development, and due to changing social behaviour and social patterns. If Asian governments fail to improve their public transport systems (railways, regional and light trains and subways, coaches, paratransit) accordingly, people will switch modes away from public transport towards individual modes. This would increase car ownership rates enormously.
Most of the governments already anticipated this trend and developed plans for the construction of the so-called Trans-Asian Railways (TAR), which are supposed to link Europe to Eastern Asia. These plans not only involve the restructuring of the formerly state-owned railway companies (privatisation), but also involve huge efforts in extending and connecting the existing national railway systems to a unified trans-national network, and re-organising railway operation with respect to timetables, fares and investment into infrastructure and often overaged rolling stock of the railway companies.

On the other hand, many of the countries concerned are poor, and are lack experience and tools and methods for the improvement of their railway systems. Therefore, this paper will introduce a comprehensive framework for a toolbox for railway development in developing countries. The toolbox is supposed to be tested for Vietnam, whose situation seems very promising for such an exercise. Privatisation of the railway company is underway, the private motorisation rate is still relatively low, and its railway system calls for improvements. Partly the tools of the toolbox are already implemented for Vietnam, partly they already exist in other contexts but still need to be adjusted to Vietnam, and partly they still need to be developed.

2 Questions to be answered

When thinking about improvements to railway systems, different interrelated questions have to be answered, such as:
- Where is demand for new lines and stations?
- Which is the optimal settlement-railway infrastructure configuration?
- Which routes and which timetable will be the most effective ones concerning construction and operation costs, travelling and maximal speed, acceleration, motor performance, energy consumption, pollution and accessibility?
- Which network topology is the most effective and reliable one concerning traffic generation, modal split, charge on stations and sections, sustainable mobility?
- Where is competition with other modes of transport?
- Which impacts on socio-economic parameters (poverty reduction, cohesion, sustainable growth, GDP) are induced?

There already exist a lot of (computer-based) tools and methods to answer the one or the other of these questions, however, a comprehensive toolbox is still lacking.

3 The current situation in Vietnam

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 1, 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, 57 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. Some of them will become part of the expanded network and get access to the national and international trade.

In January 2002 the Vietnamese Prime Minister approved *The General Plan of Development of Vietnam Railways to 2020*, stating the principal strategy to build and modernise railways infrastructure in the whole country including tracks, stations, signal system, transport means, cargo stores and railway spare parts. According to this outline plan railway traffic in 2020 should occupy the rate of 25%-30% (tons*km) and 20%-25% (passengers*km). The share of rail passenger traffic in Hanoi and Hochiminh City should grow up to 20%.

Most railway tracks are in metre gauge 1.000 mm, but in the northern regions there are two lines in 1.435 mm standard gauge and two lines in mixed gauge. New railways and especially high-speed north-south route will be built in standard gauge 1.435 mm which allows to raise speed of cargo trains up to 100km/h and of passenger trains up to 120km/h.

Figure 1: Land use, settlement structure and transport infrastructure in Vietnam: Land cover (left), settlement (middle-left), road network (middle-right), railways (right).
The expected investment is US$ 1,486 million between 2001 and 2010 (about US$ 149 million/a) and US$ 4,706 million between 2011 and 2020 (about US$ 471 million/a).

There are even plans [1] to invest US$ 38,130 million until 2025 for a double track 1435 mm gauge express railway network to raise passenger train speed up to 160-200 km/h and freight train speed up to 80-120 km/h. If construction work started in 2011, this would mean investment of about US$ 2,542 million/a. This seems hard to afford for Vietnam Railways which in 2003 had a revenue of about US$ 109 million [1] and Vietnam’s FDI in 2001 was US$ 2,472 million [4]. On the other hand, Vietnam’s GDP in 2000 was US$ 30,300 million [4].

Moreover, in 2003 the Association of Southeast Asian Nations’ (ASEAN) Land Transport Work Team involved in the trans-Asia railway (TAR) started to look for investors for the Singapore-Kunming railway project passing through Malaysia, Thailand, Cambodia, Vietnam, Laos and Myanmar [2]. The 8,135km line will use upgraded existing lines, as well as building new links between each country. A feasibility study estimated the project would cost US$ 2,500 million and take three years to complete. If Vietnam’s portion of the line is 26% this means investing US$ 642 million in Vietnam (about US$ 214 million/a).

4 Introduction to the toolbox

The proposed toolbox for railway planning in developing countries should tightly integrate tools for the optimisation of timetable and railway operation, tools for the calculation of travel demand and railway planning, tools for the impact assessment of infrastructure projects, with latest developments in modern geographical information systems (GIS). The GI systems should be used as the common basis to set up all the other tools and to provide a comprehensive and unified and un-redundant common database.

The toolbox should provide the following tools for railway planning as briefly outlined in the following sections:

4.1 Design tools

These tools should support the persons in charge of designing new railway infrastructure, in particular helping them to find optimal alignment due to special constraints and to determine locations for new stations. Such tools comprise:
- Alignment derivation (taking into account slope gradients, nature reserves, topography, bridges and tunnels etc.)
- Station and intermodal node allocation (tools to assess potential locations for new stations and shipping terminals or intermodal nodes)
- Network topology development (tools to derive new links based on transport demand evaluations)

However, design tools for the small-scale construction of tracks, bridges or stations are not foreseen.
4.2 Planning tools

These tools are dedicated to assess the service provision of existing railway lines as well as to simulate service improvements due to new railway infrastructure (new lines, new stations etc.). Moreover, these tools also support the assessment of suggested railway station catchment areas, as well as the simulation of existing and future traffic flows. This set of tools comprises

- Tool to calculate accessibility indicators for provinces (see Figure 2 as sample).
- Tool to calculate isochrone maps for selected origins based on existing or planned travel time schedules).
- Travel demand assessment (catchment areas) to evaluate the potential of train users living close to existing or planned railway stations.
- Transport and logistic chain planning
- Cost calculations
- Tools to assess socio-economic impacts of transport infrastructure projects
- Relations between mechanical parameters (mass, resistance, acceleration, speed etc.)

![Figure 2: Accessibility to population (left) and GDP (middle-left) in base scenario; relative changes in accessibility to population (middle-right) and to GDP (right) in the acceleration scenario.](image)

Accessibility is the main product of a transport system. It determines the locational advantage of a region relative to all regions. Accessibility indicators are defined to reflect both within-region transport infrastructure and infrastructure outside the region which affect the region [3]. They range from simple infrastructure measures towards complex indicators taking account of connectivity and opportunities. The most prominent type of indicators is the potential accessibility indicator, where the economic potential of a region is the total of destinations in all regions weighted by a function of distance from the
origin region. 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 \( g(W_j) \). The Planning Tools will comprise automatic tools to calculate potential accessibility indicators based on travel times and travel costs between pairs of regions.

### 4.3 Maintenance tools

These tools are dedicated to support the maintenance of existing (and planned) railway lines by means of tools such as

- Timetable visualisation, testing and optimisation (see Figure 4)
- Automated Timetable Printer (see Figure 3)
- Infrastructure and vehicles maintenance schedules development and revision

**Timetable optimisation**

Timetables are required to control train operation and to inform railway staff, passengers and freight forwarders. They are the basis for different other operation plans which support e.g. circulation of rolling stock, staff action, track occupation and loading times in stations. In the Toolbox timetables are prepared as an input to the database for further processing in the simulation program.

Timetables, as other operation plans, usually are developed on the basis of former timetables and of the operational problems they caused and of new chances offered by improved rolling stock and infrastructure.

![2003 timetable Huê-Dânang](image)

**Figure 3:** Timetable 2003 for the Huê-Dânang main section with 9 intermediate stations and 9 train pairs per day (5 express, 4 freight). From 19:50-23:33 there is a train pause for tunnel construction.

In a first approach, the Timetable tools were tested against the timetables of the Hanoi-Saigon mainline for the years 2001-2003. The whole journey from Hanoi to Saigon (1,726km or 30 to 82 hours according to train classes) may be
divided into about 10 main sections. These main sections are bordered by main stations in which all trains stop, even the fastest express trains. The main sections then may be worked independently. The timetable visualisation and testing tools display each section. So virtual train collisions may be detected one by one and trains cross and overtake in stations according to orderly operation.

In Vietnam sections between stations are not yet subdivided by blocking signals. So every station section is also a blocking section and trains cannot follow each other at denser sequence but at station distances. The tools enable to display and check the blocking sections and the times during which they are occupied and released by the trains (Figure 3).

Processing route elevation data, section speed limits and masses of the operating trains, this tool is also designed to calculate optimal driving acceleration, maximal speed and deceleration. So trains not only stop in stations in time but motor performance and energy consumption are minimised.

**Timetable simulation**

The basic idea of the *VietTrain Simulation Program* is to test the behaviour of trains under special operation disturbances (e.g. delays, blocked nodes and interrupted sections) to assess the qualities of line network, rolling stock and timetable and eventually to optimise timetables.

Until now the program is used to show that timetables work properly and without train collisions. Timetable, stations and routes are stored in the GIS database. The background is the map with indicated stations and routes. On the railway routes trains are displayed as red, green, blue or violet points with their names or codes, respectively (Figure 4). The x and y coordinates show the cursor position to define the position of stations, sections or trains. At runtime the tool shows the travelling time between 0:00 and 12:00 and 0:00 of the following day in an endless loop.

![Figure 4: Tools for timetable simulation (runtime, coordinates and trains).](image-url)
To start the simulation the user has to select the map and the database of the line network and timetable. The capabilities of this program are that the user may run, stop, restart or keep going the simulation during runtime. To modify the timetable the user may introduce new trains, routes or stations. Or he may change the speed of presentation (time-lapse) and colour of trains.

4.4 GIS database

Since all tools mentioned above are computer-based, they need to have access to a digital database. Hence, the toolbox also comprises an electronic, GIS-based database for Vietnam. All spatial information necessary to operate and further develop a railway enterprise will be stored there. Thus, the GIS database is building the ground for the other work fields. Eventually, this database could be integrated into the overall electronic database of railway companies, storing all spatial and statistical data relevant to operate such an enterprise. The contents of this database should meet the requirements of the railway company and the requirements of the tools to be developed in this project.

Moreover, once the database is set up, it represents a value of its own, since it may be used for various other purposes (e.g., passenger information system, coach tracking system, etc.). In particular, the following data will be considered:
- The entire existing Vietnam Railways system, including tracks and stations, and other railway-related infrastructure.
- Digital maps of all provinces of Vietnam, including statistical data on socio-economic phenomena as well
- Digital Terrain Model (DTM)
- A city database on towns and cities in Vietnam, including statistical data such as number of inhabitants, number of firms and households
- Natural and historical sites and phenomena database
- Landscape and river database (e.g. types of forests, biotopes)
- Competing and co-operating transport systems (inland and sea waterways, road and air transport and traffic)

Figure 1 represents a sample snapshot of the contents of this GIS database.

5 Conclusions

The paper could only give a small view on the overall contents of the toolbox to be developed. During the last years there is growing awareness that tools and models such like transport models, design, planning and maintenance tools and GIS have to be closely linked together within a comprehensive analysis framework in order to support planning processes and maintaining railway enterprises. Because of its inherent flexibility, GI-systems should form the core of such frameworks, integrating various models and tools.

Although in a first step the toolbox is to be tested for Vietnam, the tools and models to be developed may be transferred to any other (developing) country. The focus of the toolbox is (and so its major advantage) to tightly integrate all
tools in a comprehensive system, based on one single database, where all the tools and models can interact with each other. Hence, there is no need to apply different software packages for different tasks. However, in order to reach this goal some of the tools are simplified compared to latest software developments of most sophisticated approaches. Another advantage of this feature is that easier and integrated approaches allow faster assessment of different planning options (scenarios).

This reflects the opinion that in the case of developing countries it is more valuable to develop simplified but integrated tools based on one comprehensive database, instead of developing most sophisticated individual tools for each task based on various incompatible databases. However, the toolbox will be designed in a modular structure that allows to exchange individual tools in the future once improved methods are available.

References


