Evaluation of Management Strategies for the Operation of High-Speed Railways in China

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Abstract

High-Speed Train (HST) operations have recently been introduced in rail passenger transportation markets worldwide. Although the technologies for such operations have levelled at speeds of around 300 km/h, the operating parameters to be adopted in each application will differ from country to country. The operating environment will be one of the crucial success factors for the implementation of HST operations in China. This paper compares three different management/ownership models which might be used in China. The paper analyzes the characteristics of each model and proposes an optimal plan of an operational system to develop HST operations in China by using a hierarchy goals achievement matrix approach.

Keywords: High-Speed Railway, Railway Management, Hierarchy Method.

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1. Introduction

The current economic environment in China is conducive to the construction of high-speed railways. Since 1993, the Chinese government has adopted a series of effective macro-economic measures aimed at reducing the inflation rate and smoothening the pace of economic development. In 1997, the rate of increase of GDP remained at 8.8%, while the inflation rate was less than 3%. However, the increase in the GDP has slowed down since the beginning of 1998 due to the influence of the Asian economic crisis. The government expects to stimulate consumption by increasing investment especially in infrastructure. This macro-economic setting provides a very good opportunity for the development of high-speed railways. According to the central government, a total

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investment of nearly 30 billion USD will be spent on railway development from 1998 to 2002, an annual rate of 6 billion USD (Railway Ministry of China, 1998). The investment in road projects is greater than 20 billion USD annually from 1998 to 2000, mainly due to differences in investment priorities at the different levels of government. Local governments have more enthusiasm for road development, whilst rail infrastructure projects are mainly supported by central government. Investment in air transport was 1.15 billion USD in 1998 (Wang, 1999).

From the point view of environmental protection and improvement in the service level of passenger transport, HST operations are thought to be the most appropriate option (Han 1997, Qian 1995). Especially for middle distance journeys (200~700 kilometers), HST operations compare well in terms of travel time savings. China is a vast country with a population of 1.2 billion and with limited cultivable land. Thus, it is an essential policy objective to develop public transportation, which occupies the least land, possesses large capacity and consumes less energy, compared to private transportation. The high-speed railway has obvious advantages compared with highways and civil aviation. Railways, as an important national infrastructure, are not as advanced in China compared with the development of the national economy. The GDP has increased by 4.45 times from 1978 to 1996, while the operating length of the railways has been extended by only 33% during the same period (national statistical yearbook, 1997). Chinese railways rank lower than 100 in the world, in terms of the density of the railway network (track kilometers per million square kilometers).

The development of railways on a large scale has been included in the "9th Five - Year Plan (1996-2000)" by the Chinese government. The construction of a high-speed railway between Beijing and Shanghai (BSHSR) has priority. This project is aimed at promoting the economic development of a corridor along the BSHSR, the most developed belt in the Mainland, including the biggest cities such as Beijing, Tianjin, Jinan, Xuzhou, Nanjing, and Shanghai.

High-speed railways is a high technology domain, which includes new materials, new techniques and information technology. The construction of high-speed railways will not only improve the technology of railway development, but will also stimulate the development of high technology industries. In addition, it can increase the demand for material production and provide additional employment opportunities.

The BSHSR will be the largest high-speed railway project in the world with a total length of more than 1300 km. Thus, choosing an optimal mode of construction and operation has become a key factor for the success of this large infrastructure project.

Since the 1970s, railways have entered a period of decline in industrial countries caused mainly by the challenge of road and air. In order to remedy this situation, new technologies such as high-speed trains, heavy-haul transport and information techniques have been developed. Reforms of operational systems has been put forward and are beginning to play an important role in rail transportation (Ferreira, 1997a).

In England, railway reform began in 1983. Japan, which privatised the state railway and established seven railway corporations, has achieved important growth both in passenger and freight flows. Although US railways are privately owned and operated by more than 500 railway companies, their growth was stimulated by the loosening of control of railway

facilities, operation and finance policies in 1976 (Xiao, 1994).

The focus of railway reform in different countries has been putting railways into transport market as independent entities. The relationship between the government and the transport enterprises is clearly defined. There are two principal modes for these industrialised countries, the split mode and the aggregative mode.

Based on the experience of industrialised countries and the conditions of Chinese railways, we proposed three alternatives for BSHSR (two principal modes for railway operations and the traditional mode): (a) using the existing three railway administrative bureaux (traditional mode); (b) Separating operations from infrastructure (split mode); (c) Combining rail operations with infrastructure (aggregative mode) and creating a single corporation.

It should be noted that the traditional mode of construction and operation has many disadvantages in meeting the needs of a new market economy environment. This mode, which is based on the planned economy system, is the main reason for reforms in the railway policy area. The focus of this reform is to determine how to establish or reorganize the incorporated enterprises in accordance with modern economic regulations.

2. Alternatives

Two main ownership models are emerging in practice, namely, the vertically integrated railway with or without separate internal business units, and the vertically separated railway with track infrastructure managed and owned separately by multiple operators. The separation model has been adopted or proposed in some countries, notably in Great Britain, Germany, the Netherlands and Sweden (Nash & Preston 1994; Jansson & Cardebring 1989). The European Union has a policy of moving towards the separation model (Nash & Preston 1994). A similar approach has been followed for inter-State freight transport in Australia, following the competition related proposals adopted by Federal and State governments (Hilmer et al. 1993).

2.1. Traditional mode (executed by three railway administrative bureaux)

According to the present railway administrative system in China, the Beijing – Shanghai classic railways belongs to three railway administrative bureaux, (RAB), RAB of Beijing, RAB of Jinan and RAB of Shanghai, respectively (see Figure 1). The Beijing – Shanghai High-speed Railway could be divided into three sections with each being administered by one of the three bureaux.
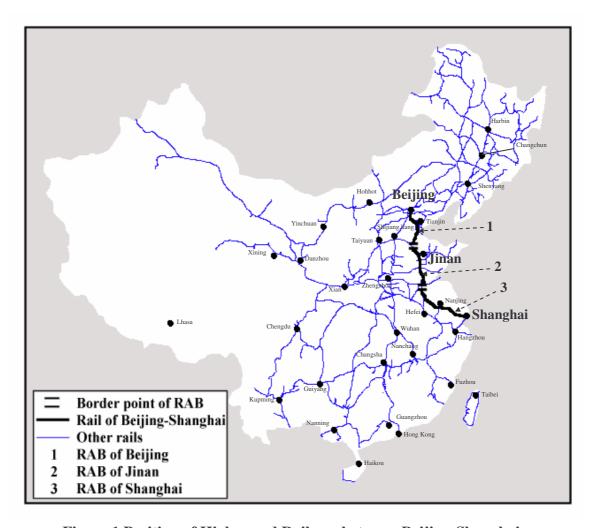
Figure 1 Position of High-speed Railway between Beijing-Shanghai

Advantages:

- This would be the preferred option of the railway administrative bureaux. Currently, the major revenues of the RABs come from passenger transportation. The conventional railway of Beijing – Shanghai plays an important role in passenger transportation (more than 200 passenger trains are operated per day). If the BSHSR were implemented, the traffic volume for both passengers and freight would increase significantly.

- Ease of coordination of the classic railway and the high-speed railway. Because both railways would be operated by the same owner, it would be easier to coordinate the freight and passenger train operations. There would be two types of passenger trains on the high-speed railway between Beijing and Shanghai,namely: the medium speed train (MST) and the high-speed train (Han et al, 1993 and Hu 1998). The medium speed trains (with maximum speeds of 160 km/h) would operate partially on conventional railways and partially on high-speed railways. The necessity of MST on BSHSR is due to: (a) the freight

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transport volume on Beijing- Shanghai corridor is quite high and the demand is steadily increasing. In order to balance BSHSR and the parallel conventional railway, most passenger trains should be operated on the former; (b) the structural speed of passenger trains on the conventional rail network is 160 km/hr; and (c) if all passenger trains used high-speed train sets, a large capital investment would be required.

Disadvantages:

● Since the RAB is not responsible for new infrastructure funding according to current policy, funding for the project would have to come from other sources.
● It would not favour the establishment of a modernized enterprise system and move high-speed railways into a market economy environment.

2.2. Split mode (separating operations from infrastructure)

Under the vertically integrated model, operators and track owners tend to have a customer-service provider relationship. The infrastructure provider exists to service the needs of its client(s). The latter may consist of several business units such as passenger services and various types of freight services. In some cases, each business group 'owns' its own track segments, which are divided amongst operators on the basis of major user. User charges may be levied to non-main users using an internal cost transfer system designed to achieve accountability and 'value for money' outcomes. It is argued that one of the drawbacks of the vertically integrated model, is its inability to readily and fairly accommodate new entrants in the form of operating competitors, sharing a common track infrastructure. If existing railway systems are publicly owned, it is possible to open up track to new entrants through direct intervention by governments. However, the question of fairness in dealing with potential competitors, would require strict contractual arrangements related to costs and service quality. The terms and operating conditions of track access need to extend to train dispatching rules.

In contrast, the vertically separated model has been put forward as a way of increasing competition in the rail sector, as well as placing rail and road infrastructure investment and operations on an equal footing. The main stated aim of the separation of track from operations in Great Britain was to ensure competition in service provision and hence improved customer service at lower costs. As competition has not yet materialised in practice, the benefits of separation may turn out to be small relative to the costs of loss of co-ordination and transaction costs, such as contract specification and enforcement (Dodgson, 1995). According to Buzelius et al. (1994), the vertical separation of railway functions in Sweden appears to have resulted in a lowering of the quality of service provided by the track owner. This model has serious implications for the overall productivity of rail operations, given the nature of the railway business, with its close independence of investments. In addition, the bargaining power of new entrants to negotiate contracts with a monopoly track owner acting to achieve commercial objectives, needs to be adequately safeguarded. The competitive pressures on train operators, which

are being sought through this model, are in danger of being absent to the infrastructure provider.

The most effective organisational model to be adopted needs to take into account the specific aims of the railway organisation(s), as well as the existing levels of efficiency, prices and customer service, as discussed in Ferreira (1997b).

Under the vertical separation model, infrastructure and train operations would be managed independently. Because of the large investment needed and the fact that the social benefit is considerable, the government should usually provide support for the construction of HSR. Meanwhile, a Passenger Transportation Corporation (PTC) would manage the operation of HSR. The structure of this approach is shown in Figure 2.
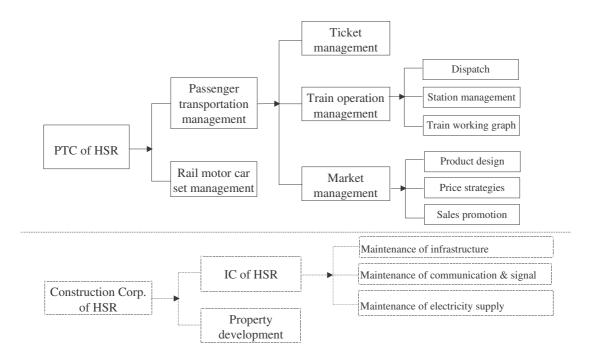

Figure 2 Structure of Split Mode Alternative

Advantages:

- The split mode model enables the release of railway transportation enterprises from the heavy burden of owning fixed infrastructure and allows them to compete fairly in the market place;
- This model would provide for a clearly defined relationship between the companies and the government;
- Facilitates cost control and hence increases the potential for commercial profits.

Disadvantages:

- The government would need to invest sufficient funds to bear the costs of the project;
- The need to coordinate the relationship between the PTC and IC, as well as the

relationship between the PTC and the relative RABs;
● Prolonged payoff period of investment in infrastructure.

The Passenger Transportation Corporation could take two possible forms:

   (a) A directly joint stock corporation. Under this model, the corresponding railway administrative bureaux become the main partners and participate in the daily business. This would facilitate the coordination of train operation both on HSR and on conventional track; and
   (b) Initially, a limited HSR company would be formed. This could be converted to a joint stock corporation of HSR at a later stage.

Economic relationship between PTC, IC and RAB

   The PTC would take charge of the operation of the HSR, including marketing, train operations management, ticketing and other technical management. The IC would take charge of the maintenance of infrastructure, communication and signalling equipment, power supply equipment, as well as property development. It would impose a fee on the PTC to partially pay for the occupation of HSR. Certain fees would also be imposed on the RAB, as the medium speed trains of the RAB would use the high-speed railway. Their relationships can be described by the diagram shown in Figure 3.
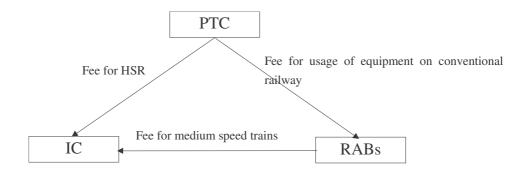

Figure 3. Economic relationships among IC, PTC and RABs

2.3. Aggregative mode (combining train operations with infrastructure management)

   This mode is still very popular in railway transportation around the world, as the infrastructure and train operations are managed and owned as a single entity. All functions, such as construction, maintenance and operation of HSR, would be undertaken by a high-speed railway group (HSRG). The structure of the HSRG is shown in Figure 4.
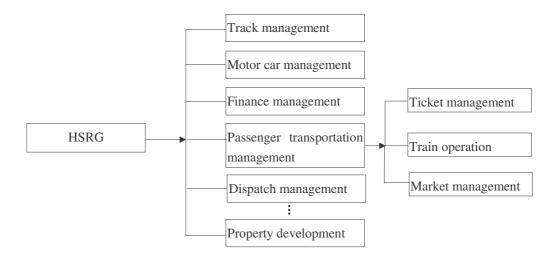
Track management

Motor car management

Finance management

HSRG → Passenger transportation management

Ticket management

Train operation

Market management

Dispatch management

Property development

Figure 4. Structure of aggregative mode

Advantages:

- Facilitates the establishment of an incorporated company and allows the high-speed railway group (HSRG) to become a self-operating and self-profiting entity;
- Facilitates the integration of all functions of the high-speed railway; and
- Reduces internal exchange costs.

Disadvantages:

- It does not favour the establishment of competition mechanisms because of the large capital investment required;
- Does not allow the analysis of cost control as compared with the split mode.

The forms of the high-speed railway group corporation:

There are two ways to establish an HSRG. One would be to directly create a joint stock corporation. This would require an extended period of time to evaluate the assets of relevant partners. The second way is to create a limited company of HSR and then to convert it to a joint stock corporation of HSR at a later date.

Economic relationship between HSRG and RABs

The HSRG would take charge of all matters concerning the high-speed railway. By using the sales network of the conventional railways, the HSRG could save on investment and may be more effective. The only disadvantage is the surrogate fee payed to the RAB. The HSRG would pay the fee for usage of equipment of the conventional railway, such as stations, motor car depots, etc. On the other hand, the medium speed trains of the RAB would borrow from the high-speed railway, so they in turn pay a fee to the HSRG.

3. Evaluation of the operating system

3.1 General

The alternative management models proposed in section 2 have been assessed in terms of the most likely net benefit to be derived from their implementation. A system based on a series of appraising indices was developed to assess each model. The multi-layer evaluation method proposed by Saaty (1978) was used at this stage. This method consists of the following steps:

1. define the general goal and the sub-goals to be achieved (G);
2. define the set of appraising indices relevant to each sub-goal (I);
3. for each of the alternatives being tested, assign relative weights for each sub-goal (B_1);
4. for each sub-goal, assign the importance of each index (B_2);
5. Assign values for each index to represent the degree to which it impacts on each alternative (B_3); and
6. Estimate an overall ranking for each alternative based on the three matrices B_1, B_2 and B_3.

This method, which has been widely applied in solving complex problems of decision making, is particularly well suited to cases where there are conflicting goals and sub-goals to be met. When each of those sub-goals have different levels of importance, it is necessary to use an evaluation framework which produces a single ranking for the alternatives being investigated.

One of the main advantages of the methodology proposed here is its transparency and ease of application. The relative rankings can be changed to reflect different weights given to each of the objectives by the main stakeholders. In this way, the sensitivity of the final results to changes in the input assumptions can be easily tested.

Establishment of a hierarchy model

In the current application, a hierarchy model was used, consisting of 4 layers and 11 indices. The latter were selected specifically to cover the range of indicators which decision makers are likely to be most concerned with when assessing each of the three alternative models proposed here. Indices which have less influence on the selection of the optimal alternative were excluded at this stage. However, the methodology can easily be adapted to include other indices such as economic impact factors, in addition to the financial factors which have been included..

The first layer consists of the general goal which is to select a preferred model from the three alternatives. The second layer includes three sub-goals: financial benefits, social effects and enterprise management. In the third layer, 11 indices have been put forward that correspond to the three sub-goals. The last layer comprises the three alternatives (see Figure 5).
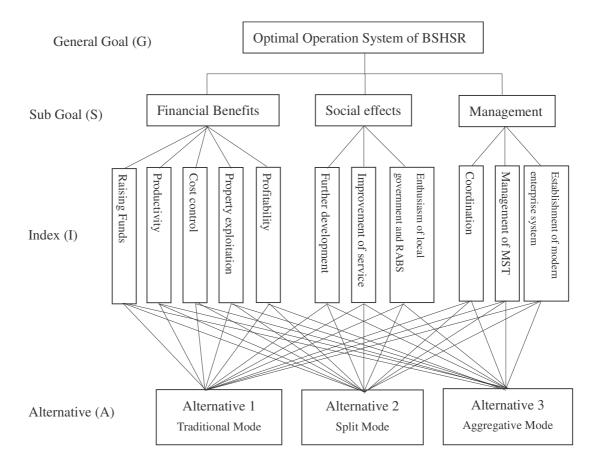
Figure 5. Structure of the multi layer evaluation system

Determination of the index value

Most indices used are qualitative in nature. The values used for each index were arrived at using a panel of experts in each field. The basic relationships between each index and the three alternatives are discussed below.

Fund raising. The Beijing-Shanghai High Speed Railway is a large-scale project and the raising of funds is a key factor to its success. The experts proposed several methods of fund raising such as:

(a) Government infrastructure investment funding;
(b) additional charges on freight and passengers carried on the existing railway between Beijing and Shanghai;
(c) stocks or bonds issued on domestic market or international market and bank loans.

Alternative 1 has less flexibility in fund raising than the other two. Alternative 3 may be more favourable at fund raising than 2, as it integrates the whole high-speed railway system. The preferred order for raising funds is alternatives 3, followed by 2 and 1.

Cost control. Alternatives 2 and 3 are more effective than 1 because they will result in independent entities being formed. Alternative 3 reduces internal exchange costs

compared to 2. However, it is easier to control costs in the split mode model than in the aggregative model, because the PTC of HSR does not need to consider the burden of fixed assets. The preferred order for cost control is alternatives 2, 3 and 1.

Productivity. The PTC in the split mode can enter the transport market without the heavy burden of fixed capital requirements. Alternative 2 has the potential to result in higher productivity than the other two alternatives. Alternative 3 will be more productive than 1 because of its modernized operating system.

Property development. Alternative 3 has a slight advantage as it can better tailor land use and property needs to the level of passenger demand being forecast.

Profitability. This is a very important index for an enterprise. The split mode model would have potentially the highest profitability, as the PTC has the least capital burden. The modern incorporated mode (alternative 3) could have a more efficient system and its profitability is likely to be higher than in alternative 1.

Further Development. The establishment of a modern enterprise system will ensure the further development of high-speed railway in China. Alternatives 2 and 3 will be more favorable in this respect. Considering current trends in world railway operations and management, alternative 2 would have a higher value than alternative 3.

Improvement in the level of service. In alternative 2, the PTC can compete fairly with other transportation modes and gradually improve its service level compared with the other two alternatives. As the traditional mode lacks flexibility, it is likely to be in improving service levels. The preferred order for level of service is alternatives 2, 3 and 1.

Enthusiasm of local government and RABs. Alternative 1 is the most favorable for RABs because they can get the largest profits from the project without large investment. Local governments may find easier to become a shareholder in alternative 2 compared to 3. The preferred order for enthusiasm of local government and RABs is alternative 1, 2 and 3.

Coordination. Since alternative 2 calls for coordination between the PTC, the IC and RABs, this model has the lowest value. It would be easier to coordinate the HSRG with RABs than to coordinate between the three RABs. The preferred order for coordination is alternative 3, 1 and 2.

Management of MST. Because of the features of passenger flow and the current situation of the Chinese railways, it is indispensable to operate medium speed trains on the BSHSR for a long period after the BSHSR is constructed. Alternative 1 has an advantage because the same owner would operate both the HSR and the existing rail network.

Establishment of modern enterprise system. Under alternatives 2 and 3 there is a need to establish a modernized enterprise system. Alternative 1 needs a longer period to convert to

a modern system.

3.2 Results

In order to arrive at an overall ranking for the three alternatives, a survey of experts was undertaken. The results of that survey enabled comparison matrices to be built for each of the 11 indices selected. The precedence matrix, showing the value of the relative weight of each alternative corresponding to each index, is given by:

$$
B_3 = \begin{pmatrix}
0.204 & 0.263 & 0.27 & 0.282 & 0.252 & 0.244 & 0.238 & 0.393 & 0.349 & 0.393 & 0.208 \\
0.306 & 0.395 & 0.405 & 0.352 & 0.379 & 0.39 & 0.429 & 0.327 & 0.233 & 0.28 & 0.396 \\
0.490 & 0.342 & 0.324 & 0.366 & 0.369 & 0.366 & 0.333 & 0.28 & 0.419 & 0.327 & 0.396
\end{pmatrix}
$$

In matrix B_3, the sum of each column representing each index is 1.0. The higher each individual value is, the higher the relative score for each alternative. For example, 0.204, 0.306 and 0.49 represent the weights for the three alternatives in the index related to funds raising. In this example, alternative 3 has an obvious advantage in funds raising. Whilst alternative 1 is the weakest in relation to the same index.

The decision on the weights to be assigned to each factor is crucial in the decision-making process. The results of the survey of experts, expressed by a precedence matrix which reflects the three sub-goals, are given by:

$$
B_2 = \begin{pmatrix}
0.38 & 0.17 & 0.16 & 0.11 & 0.18 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.38 & 0.43 & 0.19 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.28 & 0.3 & 0.42
\end{pmatrix}^T
$$

In matrix B_2, the eleven indices are divided into three groups corresponding to three sub-goals. For example, the value of 0.38, which is the relative weight of fund raising in the first group, is the most important factor in this group. In other words, the first row represents the weights of the 11 indices to sub-goal one, namely, financial benefit.

For the first layer, the prior matrix is shown below, in which the weight of the three sub-goals is given. The sub-goal of social benefits has the highest value, as the railway is a public infrastructure good.

$$
B_1 = \begin{pmatrix}
0.355 \\
0.395 \\
0.250
\end{pmatrix}
$$

Thus, according to the principle of the hierarchy method, the precedence matrix for the three alternatives in terms of the three sub-goals is given by:

$$W^3 = (B_3)_{3 \times 11} \cdot (B_2)_{11 \times 3} = \begin{pmatrix} 0.241 & 0.270 & 0.303 \\ 0.355 & 0.395 & 0.316 \\ 0.404 & 0.335 & 0.381 \end{pmatrix}$$

From this matrix, it can be found that alternative 2 is the best according to social benefit, while alternative 3 would be optimal in terms of the other two sub-goals.

The final matrix for the three alternatives, in terms of the general goal, can be estimated by:

$$W^4 = W^3 B_1 = (0.268, 0.361, 0.371)^T$$

From the above results, it was found that alternatives 2 and 3 are valued much higher than alternative 1.

3.3 Limitations of the methodology

The method used to rank alternative railway management models is able to provide a quantified final ranking which can be used to select those alternatives with high relative scores. Lower ranked alternatives can be discarded from further analysis at this stage. Therefore, the method is appropriate for a first screening of alternatives to be further assessed during a more detailed investigation of impacts.

The use of relative weights at several stages in the procedure in order to rank sub-goals, indices and alternatives, relies on a large degree of subjectivity on the part of the panel of experts. The fact that the process calls for single values to be assigned to each weight means that a different set of experts could yield different values for the same weights. Although this inherent subjectivity can be minimized by the appropriate use of experts, the overall results obtained should be seen as central values with uncertainty distributions attached to each ranking value. As a result, alternatives which have close overall performance rankings are likely to need to be further investigated before a final result can be obtained. The level of uncertainty in the estimation of the relative weights for each index is likely to be higher if the alternatives being assessed are new and differ significantly from established management models. This is the case of new railway management and operating models applied in China. The panel of experts used to arrive at the weights for each index needs to undertake impact assessments which may be difficult to quantify, in the absence of past experience in the Chinese railway context.

Another limitation of the method is the potential for bias on the part of the analyst through the definition of appropriate indices for each sub-goal, as well as the relative importance of those indices. The exclusion of some indices, or the downplaying of their importance, could influence the overall results significantly.

The impact of the shortcomings of the methodology is significantly reduced by the

way in which the entire process is made transparent to the decision-maker. Since the weights used at each stage are subject to scrutiny and review, it is possible to detect and correct for any bias which may be evident.

4. Conclusions

The results imply that the Chinese railways have to embark on significant reform in the operational system in order to adapt to a market economy. The central government of China has decided to create a high-speed railway between Beijing and Shanghai, and we have proposed the establishment of a modern entity by applying the prior experiences of industrialised countries.

Comparing the split mode with the aggregative mode, it seems that the latter is slightly more attractive (0.371) than the former (0.361). This may be because the first index (compensation and raising of construction funds) has a very important influence. With the reinforcement of an integrated national power and the push for railway reform, the split mode may become the optimal alternative, although the aggregative model is currently recommended.

The recent reform policy of national enterprises shows the trend in establishing a modern corporation system. The construction and operation of BSHSR will be managed by a corporation body, though the main investment will come from the central government. It is proposed to create a new independent enterprise outside the existing rail system. Therefore, the HSR corporation needs to coordinate with the three railway administrative bureaux (Beijing, Jinan and Shanghai). The high speed railway will play a very important role in improving the transportation level of service between large urban centres.

List of acronyms

BSHSR: High-Speed Railway between Beijing and Shanghai
HSR: High-Speed Railway
HSRG: High-Speed Railway Group
HST: High-Speed Train
IC: Infrastructure Company
MOR: Ministry of Railway
MST: Medium Speed Train
PTC: Passenger Transportation Corporation
RAB: Railway Administrative Bureau

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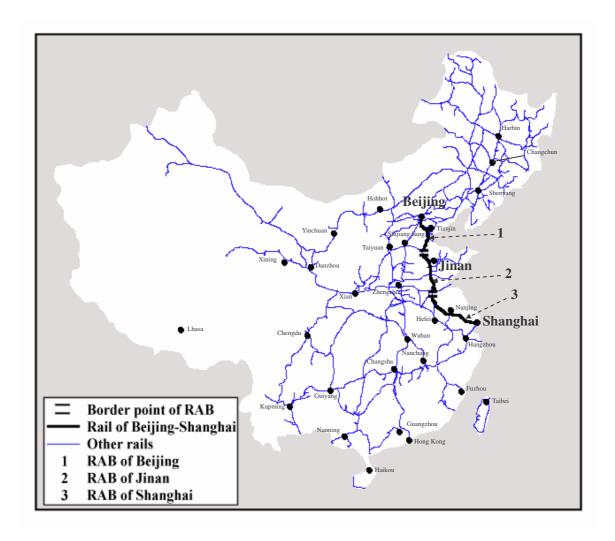
Study of railway development. China

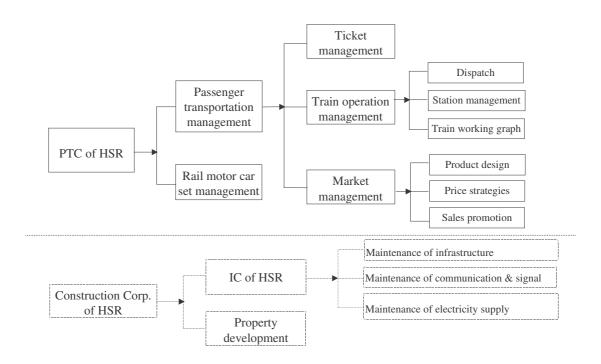**Figure 1 Position of High-speed Railway between Beijing-Shanghai**
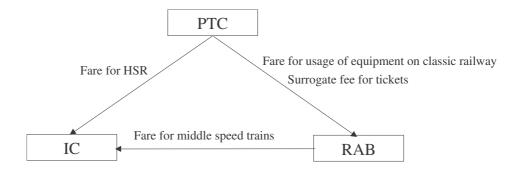
Figure 2 Structure of Split Mode

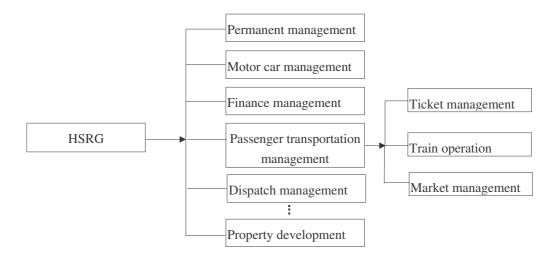**Figure 3. Economic relationships among IC, PTC and RAB**
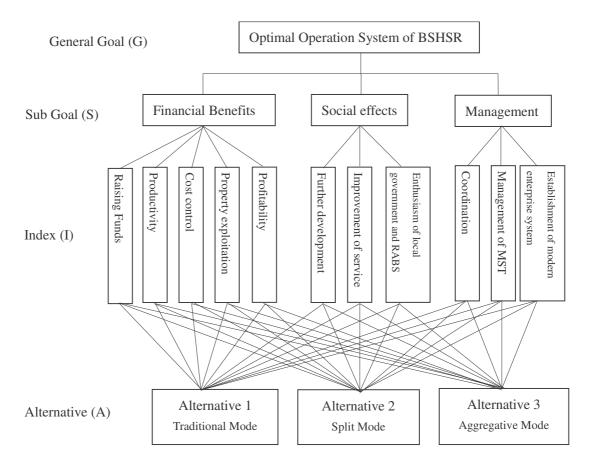
Figure 4. Structure of aggregative mode

Figure 5. Structure of the multi layer evaluation system