Economic statistical strategies for the transportation industry based on time-varying parametric state space models

Wanli Fang¹,†, Qingping Huang²
1. Business College, Hohai University, Nanjing, 210036, China
2. Business College, Jiangsu Open University, Nanjing, 210036, China

Abstract

Under the new situation, the speed of economic development continues to accelerate, and under the influence of the modernization process, the transportation industry is more closely linked with the economy. To promote the sustainable development of the transportation industry, it is necessary to establish a scientific and effective economic statistics strategy to achieve steady economic growth. This paper designs a segmented time-varying parametric state space model based on the state space model to construct an economic statistical system for the transportation industry. By integrating and breaking the original design model, the structure, function, and statistical process of the system are optimized. The system is introduced into the transportation industry to analyze the application effect. According to the data, the economic revenue of the railroad transportation industry reached 464.293 billion yuan at the end of 2021, 45.48 times more than that of 10,208.81 billion yuan in 1986, and the market share increased from 23.23% in 2000 to 31.19% in 2021. The market share of waterway transportation industry, on the other hand, rose from 29.07% in 2000 to 32.87% in 2021. The share of capital investment in waterways and civil aviation continues to change in a downward trend from about 11% in the previous period. The economic statistics strategy can improve the economic efficiency of the transportation industry, so that the whole industry can gradually adapt to the current level of economic development and the needs of people’s life.

Keywords: Keyword State-space models; Transportation industry; Economic statistical systems; Market share; Transportation modes

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1 Introduction

As an important basic service industry of national economy, transportation industry has a first strategic position in national economy and social development, and it has very close connection with other sectors of national economy [1-3]. Its rapid development is a basic guarantee for the healthy and orderly development of the national economy. And perfect transportation statistics are important to support a comprehensive understanding of the scale and structure of transportation industry development, scientific planning of transportation network and transportation infrastructure construction, and reasonable allocation of transportation capacity and capability [4-6]. Therefore, it has been highly valued by the transport management. The contribution of the transportation industry is not only in the benefits of the industry itself, but also in its contribution to the society as a whole and to other sectors of the national economy [7-8]. Its contribution to the society as a whole and to other sectors of the national economy greatly exceeds its own production benefits [9-10]. Therefore, when examining the socioeconomic benefits of the transportation industry, it is important to consider not only its direct economic benefits but also the indirect economic benefits that arise from its services to other sectors [11-13]. In addition, since the transportation industry has a great driving role in promoting the development and prosperity of the region in addition to generating economic benefits [14]. This benefit is difficult to calculate quantitatively, but it is very important. It is necessary to establish the concept of development, change the thinking, actively adapt to the characteristics of the current stage, analyze the characteristics of the transport economy, and improve on the original basis, improve the measures to provide a superior economic statistical strategy for the development of the transport economy [15-16].

Modern transportation system includes five modes of transportation, such as railroad, highway, water transportation, air transportation and pipeline. These five modes of transportation have their own advantages, writing for each other and complementing each other to form China’s transportation system. According to China’s national conditions and level of economic development, the transportation system plays a pivotal role and has been extensively studied. Three unsupervised feature extraction methods based on causal networks have been proposed in the literature [17]. Precisely, after discovering the causal networks among the monitored variables in a rail transit system, the principal components associated with a specific fault are extracted from the causal intensity matrix or from the complete causal intensity matrix constructed from the causal networks. The effectiveness of the proposed method is verified on two public datasets and a real dataset considering high-speed train braking systems, compared to existing correlation-based feature parsimony methods. In the literature [18], a railway-centered multimodal transport path selection model is developed with the background of China’s huge railroad network and advanced heavy-duty technology, introducing the time penalty cost and damage compensation cost, and taking the lowest comprehensive transport cost as the model objective while considering transport reliability and transport safety. Finally, the model is solved by an improved ant colony algorithm using the Chinese multimodal transport network as an example, and the results verify the reasonableness of the model. In the literature [19], a multi-class price railroad passenger ticket allocation optimization method with high passenger demand is proposed. First, an unconstrained model of railroad passenger demand is constructed for the “missing data” problem in railroad passenger demand forecasting, and the unconstrained demand is solved by an expectation maximization algorithm. Then, based on this model, a gray neural network is used to predict passenger demand at different origins and destinations, and two methods of ticket allocation based on operation and capacity control are proposed: the exact pre-segmentation model and the fuzzy pre-segmentation model. In the literature [20], the optimal cold chain logistics transportation scheme was determined using traditional genetic algorithm and A-SAGA. In addition, sensitivity analyses were conducted on freight subsidies, train travel speed, soft time window and carbon tax rate. The results showed that for medium- and long-haul cold chain transportation, the rail market share
increased from 17.55% to 18.75% and the share of rail freight subsidy increased from 0% to 30%.

Literature [21] Digital transformation of business models is now crucial for the development of the rail transport sector through innovative technologies that help traditional business solutions to achieve new functionalities. The main railroad market entities are railroad companies, infrastructure managers, entities responsible for maintenance or certification bodies. Digitization creates new opportunities to shape the business ecosystem of the rail transport industry. It is clear from the above literature that the transportation industry is not only a carrier of China’s economic development, but also creates important conditions for the development of China’s economy and society. To promote the level of economic development of the transportation industry, it is of special importance to explore the forward direction and path of economic reform in depth.

China’s socialist market economy system is continuously established and improved, and the national economy continues to develop. The transportation industry must develop relevant economic statistics strategies. To increase the development of transportation industry and adapt to the needs of national economic development. In this paper, a segmented time-varying parametric state space model is constructed based on the state space model. The model is used to generate and upgrade parameters to recursively update the time-varying parametric approximation of the posterior distribution. Based on the current application status of the systems at all levels of transportation statistics, a time-varying parametric state-space model is used to integrate the statistical systems at all levels and obtain a three-level integrated economic statistical system for the transport industry. The design goal of the system is to achieve complete automation of daily transport production and economic information statistics for management departments at all levels of the transport industry, to provide timely, accurate and reliable auxiliary economic decision-making information for the development of the transport industry, and to provide a reliable guarantee for tapping potential and improving efficiency in the field of transportation.

2 Time-varying parametric state space model

2.1 Base model construction

Many models in the transportation industry economy can be expressed in the form of state-space models; for example, typical linear regression models, ARIMA models, and SV models can be expressed as special cases in the form of state-space models [22]. Based on the existing state space model, a segmented time-varying parametric state space model is designed. Assume two stochastic processes $\theta_t$, $t = 1, 2, \ldots$. Assume that the two stochastic processes and depend on the segmented time-varying parameters, $\theta_t$, $t = 1, 2, \ldots$. Assume that the two stochastic processes and depend on the segmented time-varying parameters, $\theta_t$, $t = 1, 2, \ldots$. $\theta_t$ is the observation-valued process and $X_t$ represents the state variable of the target at moment $t$, assuming an initial distribution density of $p(x_0 | \theta_0)$ [23-24]. The state process $X_t$ and the observation-valued process $Z_t$ have probability distribution densities of the form:

State transfer equation:

$$X_t | X_{t-1} = x_{t-1} : p(x_t | x_{t-1}, \theta_t)$$

Measurement equation:
Where the state variable $X_t$ obeys a Markov process conditioned on the previous states $X_{t-1}$ and parameters $\theta_t$, and the observation $Z_t$ at moment $t$ is conditioned on the state $X_t$ at moment $t$. The information of the observation $Z_{t|t}$ is known as follows:

$$Z_t \mid X_{t-1} = x_t : p(z_t \mid x_t, \theta_t)$$

(2)

To satisfy this condition, it is necessary to determine the filtered posterior distribution $p(x_t \mid z_{t|t}, \theta_t)$ for moment $t$. According to the recursive Bayes rule, the following equation can be obtained:

$$p(x_t \mid z_{t|t}, \theta_t) = \frac{p(z_t \mid x_t, \theta_t) p(x_t \mid z_{t|t-1}, \theta_t)}{p(z_t \mid z_{t|t-1}, \theta_t)}$$

(4)

Among them:

$$p(x_t \mid z_{t|t-1}, \theta_t) = \int p(x_t \mid x_{t-1}, \theta_t) p(x_{t-1} \mid z_{t|t-1}, \theta_t) dx_{t-1}$$

(5)

$$p(z_t \mid z_{t|t-1}, \theta_t) = \int p(z_t \mid x_t, \theta_t) p(x_t \mid z_{t|t-1}, \theta_t) dx_t$$

(6)

The two equations above are the predicted distribution and the integration constant, respectively.

Estimation is performed using a time-varying parametric state space model $p(x_t \mid z_{t|t}; \theta_t)$, i.e., a discrete random sample with corresponding weights $\{w_{t|i}^{(i)}\}_{i=1}^{N}$ or parameters $\{x_{t|i}^{(i)}\}_{i=1}^{N}$ is used to approximate this posterior distribution, as follows:

$$p(x_t \mid z_{t|t}; \theta_t) \approx \sum_{i=1}^{N} w_{t|i}^{(i)} \delta_{t|i}^{(i)}(x_t)$$

(7)

Where $\delta(\cdot)$ is the Dirac Dale hedge function and each parameter $x_{t|i}^{(i)}$ has a weight $w_{t|i}^{(i)}$, and $N$ is the number of parameters. The time-varying parameter approximation of the posterior distribution can be updated recursively by using the model to generate and upgrade the parameters.

### 2.2 Model optimization

To solve the nonlinear problem of transportation industry economy, the time-varying parametric state space basis model is optimized based on jump Markov linear system.

Consider the general jump Markov linear system:

$$x_t = A(r_t) x_{t-1} + B(r_t) w_t$$

(8)

$$z_t = C(r_t) x_t + D(r_t) v_t$$

(9)
Where \( x_k \in \mathbb{R}^{n_x} \) is the basic state. \( r_k \in \{1, 2, \ldots, N_r\} \) is the type of state variable of the model, \( y_{nk} \) is the observed value, and \( w_k \in \mathbb{R}^{n_w} \) is the state process noise distribution and obeys a normal distribution. That is, \( w_k \sim N(0, Q) \), \( v_k \in \mathbb{R}^{n_v} \) is the measurement process noise distribution and obeys a normal distribution. Namely:

\[
u_k \sim N(0, R), A(r_i), B(r_i), C(r_i), D(r_i)\]  

(10)

The above equation is an appropriate scale matrix function. The type of state variable can be modeled as a chi-square Markov chain. Where the transfer probability matrix is shown as follows:

\[
p(x_k | z_{0:k})
\]

(11)

\[
\pi_{ij} \Delta p(r_i = j | r_{i-1} = i)
\]

(12)

The optimized model approximates the posterior conditional probability distribution \( p(x_k | z_{0:k}) \) as follows:

\[
p(x_k | z_{0:k}) \approx \sum_{i=1}^{N_r} \mu_i N(x_k | \hat{x}_{k|k}^i, \sum_{k|k}^i)
\]

(13)

Where \( \mu_i \sim p(r_i = i | z_{0:k}) \) is denoted as the posterior conditional probability distribution of the type of state variable \( r_i \in \{1, 2, \ldots, N_r\} \). The entire posterior mean \( \hat{x}_{k|k}^i \) and covariance \( \sum_{k|k}^i \) can be easily calculated using the standard normal mixed mean and covariance formulas, as follows:

\[
x_{k|k}^i = \sum_{i=1}^{N_r} \mu_i \hat{x}_{k|k}^i
\]

(14)

\[
\sum_{k|k}^i = \sum_{i=1}^{N_r} \mu_i \left[ \sum_{k|k}^i + (\hat{x}_{k|k}^i - \hat{x}_{k|k}^i)(\hat{x}_{k|k}^i - \hat{x}_{k|k}^i) \right]
\]

(15)

3 Economic statistics system for transportation industry

Based on the current application status of systems at all levels of transportation statistics, a time-varying parametric state-space model is used to integrate statistical systems at all levels. The original design model is broken, and system structure, function, and statistical process optimization is carried out. By establishing a three-dimensional data information base of time, intervals and vehicles, the full sharing and utilization of basic information resources is realized [25-27]. To build a traffic three-level integrated statistical analysis system that meets the statistical needs of various departments at all levels of the road. The three-level integrated statistical analysis system of transportation industry obtains rich and complete basic data sources by sharing with various related basic information in “cargo transportation management system”, “vehicle dispatching command system”, “automatic vehicle number identification system” and “traffic organization planning system” [28-30]. After the integration of these information processing, a powerful statistical analysis management infrastructure information system is formed. It changes the disadvantages of the original database which is placed scattered and cannot be shared fully with each other [31]. A unified database is constructed at the Ministry of Transportation or the Department of Transportation to centralize and share statistical data, and to update vehicle access information, transport non-state transformation information, and loading and unloading operation information of the station in real time [32-33]. Combined with the operation
chart information from the dispatching information system of the transportation bureau, the transportation department or the transportation bureau selects the corresponding time points, conducts centralized and unified statistical index preparation, generates various statistical reports, and feeds the relevant statistical results to the grassroots stations and sections [34]. The architecture of the system is shown in Figure 1.

![Schematic diagram of the structure of the three-level integrated economic statistics system for transportation](image)

**Figure 1.** Schematic diagram of the structure of the three-level integrated economic statistics system for transportation

The three-level integrated statistical analysis system of transportation industry can generate reports of transportation bureau, section, and station in real time according to vehicle category and unit category at the level of transportation bureau. The powerful information release function of the system can release the relevant statistical information to the clients of the grass-roots stations and sections in real time, and at the same time send it to the Ministry of Transport and relevant management departments. The indicators of stations, sections and traffic bureaus at any time can be extracted for analysis and displayed visually to users in a graphical mode, so that they can understand the completion of transport production business in each department in real time. The system has the following three-level functions in the Department of Transportation and the station section of the Department of Transportation.

1) **Department of Transportation.** The main functions of the system are receiving and reviewing the reports of each traffic bureau, generating indicators of the Ministry of Transport, querying, and analyzing indicators of subordinate units, publishing indicators of the Ministry of Transport externally, publishing indicators of subordinate units, and analyzing the transport production status of the Ministry of Transport.

2) **Traffic Bureau.** The main functions of the system: receiving and reviewing the original information of the station, reading the information of vehicles in transit, generating all indicators of the Traffic Bureau, querying, and analyzing the indicators of the station, publishing the indicators of the station, and analyzing the production status of the Traffic Bureau.
3) Station section. Main functions of the system: confirmation of truck access, registration of non-transformation, confirmation of loading and unloading operations, generation of station indicators, reception of production indicators, and analysis of station production status.

4 Analysis of the application of economic statistical strategies in the transportation industry

4.1 Economic income of railroad transportation industry

Railroads are the main artery of China’s national economy and an indispensable part of the transportation system. It has made its due contribution to the smooth socialist construction and the improvement of people’s life, so this session is devoted to the study of railroad transportation industry. Figure 2 shows the transportation revenue of China’s railroad transportation industry from 1986 to 2021 and the transportation revenue after leveling off. The overall revenue of China’s railroad transportation industry has been increasing, especially after 2007, and the transportation revenue reached 464.293 billion yuan at the end of 2021, which is 45.48 times higher than that of 10,208.81 billion yuan in 1986. According to the decision result of the statistical system, considering the change of price index, the value-added index of transportation, storage and postal industry is used to perform deflating operation on it, and the deflated transportation revenue is obtained as shown in the figure. The trend of change in transportation revenue after deflating grows more slowly, relatively speaking, there is a substantial increase after 2007, and the overall trend is upward, with significant advantages. This is because the system can meet the economic statistics needs of all departments at all levels of the road by establishing a three-dimensional data information base of time, intervals, and vehicles, and realizing the full sharing and utilization of basic information resources.

Figure 2. Transportation revenue of the railroad transportation industry
4.2 Transportation turnover comparison

The transportation industry differs from the general industrial industry in that its output can be measured in terms of passenger traffic and freight turnover in physical form, in addition to the transportation revenue that exists in value form. The transportation industry ranks first in the world in terms of passenger turnover, cargo dispatched, cargo turnover and converted turnover, and has formed a more complete network system. Passenger turnover is the product of the number of passengers (People) transported in a certain period and the distance (Kilometers), the unit of measurement is “person-kilometers”. And freight turnover is the product of the number of goods transported (Tons) and the distance transported (Kilometers), the unit of measurement is “ton kilometers or ton nautical miles.

1) Passenger traffic volume

Figure 3(a) shows the passenger turnover of the four different modes of transportation in China. Between 2000 and 2003, the passenger turnover of China’s railroad and road transport industries were still relatively close. Since 2003, passenger turnover by road has risen sharply, reaching 185,236,600 million passenger kilometers by the end of 2021, 1.92 times the passenger turnover by rail and 3.71 times the passenger turnover by air in the same period, gradually becoming the most dominant mode of passenger transport. And at the same time, the absolute value of passenger turnover of railroad is also rising, taking the second place, and the passenger turnover of air transportation is also showing an upward trend, and all three have increased the rise after 2012. The passenger turnover of water transport has been at a low level, which mainly stems from the technical and economic conditions of water transport itself cannot be improved by economic statistical strategies, therefore, it has been on a downward trend since 2010, and has produced a huge gap with the other three modes of transport.

2) Freight turnover

Figure 3(b) reflects the freight turnover by mode of transport. the freight turnover of waterway transport (excluding ocean transport) and rail transport industry has been maintaining an upward trend, and the rise has increased after 2012. The freight turnover of roads developed slowly during 2000-2006 and surged and increased significantly since 2006, reaching 59,623,382 million ton-kilometers of freight turnover in the road transport sector by the end of 2021, which is about 2.03 times more than the 2,929,310 million ton-kilometers of freight turnover in the rail transport sector during the same period. The cargo turnover of aviation has been at a low level, but in terms of specific data, it still maintains an overall upward and growing trend.

3) Conversion of turnover

When comparing the output of different modes of transportation, due to the differences in the functional nature of each sector and price control, the indicator of transportation revenue then lacks comparability, thus using turnover for comparison, and using converted turnover for conversion based on passenger turnover and freight turnover. Converted turnover means converting passenger turnover into cargo turnover by a certain percentage, and then adding it with cargo turnover to form a converted turnover indicator including passenger and cargo transportation. It integrates the total passenger and cargo turnover completed by various means of transportation in the reporting period and is a comprehensive output indicator for assessing the transportation industry. Calculation formula: Conversion turnover = cargo
turnover + (passenger turnover + passenger-cargo conversion factor). The size of the passenger and cargo conversion factor depends on the amount of manpower and material resources used to transport 2-ton kilometers and 2 person kilometers. The current statistical system provides for the passenger and cargo conversion coefficient of 1.2 for railroads, 0.34 for inland rivers, 0.11 for roads, 0.075 for domestic aviation and 0.078 for international. So, use the above coefficients for conversion, that is: railroad conversion turnover = freight turnover + passenger turnover × 1.2. road conversion turnover = freight turnover + passenger turnover × 0.11. Waterway conversion turnover = freight turnover + passenger turnover × 0.34 civil aviation conversion turnover = freight turnover + passenger turnover × 0.075.

After conversion in the above way, we can get the converted turnover of various modes of transportation, also called the integrated turnover. From Figure 3(c), we can see that the overall trend of China’s transportation industry is on the rise and developing well. Road converted turnover jumped to the first place in 2017 after the financial crisis, accounting for 41.23% of the total combined turnover. This is because the economic statistics strategy of the transport sector designed in this paper creates conditions for the transport development of roads in the national networking model and maintains the upward trend, with a share of 48.3% of road transport turnover by 2021. The combined railroad turnover and the combined waterway turnover maintain a relatively slow growth trend, with the market share of the railroad transportation industry rising from 23.23% in 2000 to 31.19% in 2021, and the market share of the waterway transportation industry rising from 29.07% in 2000 to 32.87% in 2021. At the same time, the air transport industry is also at a lower level to maintain a slow rise.

(a) Transport mode passenger turnover
(b) Transport mode freight turnover

(c) Transport mode conversion turnover

**Figure 3.** Comparison of turnover of transportation industry
4.3 Capital investment in the transportation industry

![Figure 4. Share of the original value of fixed assets in the transportation industry](image)

The smaller the share of the original value of fixed assets, the lower the amount of depreciation will be, and the greater the net income in the current period, the more beneficial to the economic development of the entire transportation industry and improve the economic efficiency of the industry. Therefore, this experimental session explores the impact of the system on the economy of the transport sector in terms of the share of the original value of fixed assets of each transport sector. Figure 4 shows the share of the original value of fixed assets of each transport mode in the combined original value of fixed assets of each transport mode (i.e., the sum of the original value of fixed assets of each transport mode in the year). As you can see from the above diagram, the built system achieves rich and complete basic data sources by sharing with various related basic information in “cargo transportation management system”, “vehicle dispatching command system”, “automatic vehicle number identification system” and “traffic organization planning system”. After processing and integrating this information, it solves the problem that the original databases are scattered and cannot be fully shared with each other, so that economic data can be centralized, shared, and updated in real time. Therefore, it leads to the trend change of the proportion of the painted fixed assets investment in railroads and waterways decreasing year by year, and the proportion of fixed assets investment in railroads decreasing from 45.23% in 2005 to 25.34% in 2017, while the proportion keeps increasing after 2017. This stems from the large-scale capital investment in railroads. In contrast, the share of capital investment in roads remained roughly around 55% and reached 61.23% over the sum of the other three modes of transportation in 2017, before decreasing after 2017. The share of capital investment in waterways and civil aviation continues to change in a downward trend from the previous period’s share of about 11%. This indicates that each transportation sector has achieved a larger net gain in the current period in the practice of economic statistics strategies.

5 Conclusion

In this paper, a three-level integrated economic statistical system for the transportation industry is constructed by establishing a time-varying parameter state space model. By integrating economic
statistical systems at all levels, the system structure, functions and statistical processes are optimized to form a powerful statistical analysis and management basic information system. The integrated system will be utilized in the transportation industry. After analyzing the current economic situation of the transportation industry, the overall revenue of the industry is increasing, especially after 2007, when it rose significantly. Among them, the railroad transportation industry reached 464,293 million yuan in transportation revenue at the end of 2021, 45.48 times more than 10,208,881 million yuan in 1986. Passenger traffic turnover by road rose sharply, reaching 185,236,600 million passenger kilometers by the end of 2021, 1.92 times the passenger traffic turnover of railroads and 3.71 times the passenger traffic turnover of airlines in the same period. The freight turnover of the four transportation sectors has been maintaining an upward trend. The market share of rail transportation industry has increased from 23.23% in 2000 to 31.19% in 2021, while the market share of waterway transportation sectors has been maintaining an upward trend. The freight turnover of the four transportation sectors has been maintaining an upward trend. The market share of rail transportation industry has increased from 23.23% in 2000 to 31.19% in 2021, while the market share of waterway transportation industry has increased from 29.07% in 2000 to 32.87% in 2021. And at the same time the air transportation industry is also at a lower level to maintain a slow rise. The above analysis shows that the integrated economic statistics system has promoted the development of the transportation industry, improved the transportation capacity of the transportation industry, and made the transportation industry gradually adapt to the needs of economic development and improvement of people’s life.

References


