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Economic Benefit Analysis of the New 3X Series EMUs

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ABSTRACT

At present, the high-speed railway in China is facing many problems, such as financial losses, unbalance of passenger flow, insufficient train capacity and poor comfort, etc. Based on the characteristics and advantages of 3X industrialization platform series EMUs, this paper explicitly proposes that 3X series emus is one of the most effective ways to solve the existing problems of high speed railway. Based on the Beijing-Guangzhou high-speed railway, the paper studies the expected economic benefit of the new high-speed railway through the two paths: cost saving and income increase. According to the long-term plan of China' s national and railway development, we make a prediction about the total economic benefits of the new trains in 2020 and 2025. Through qualitative and quantitative analysis, we conclude that 3X series EMU has achieved great improvement in advancement, practicality, and comfort etc., which is a new product that perfectly adapts to China's national conditions and development prospect of railway.

1 Overview

High-speed railway transportation has the

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advantages of large volume, low transportation cost and strong continuity with the characteristics of rapid, convenient, economic, environmental protection and safety. In modern times, it is an important mode of transportation and an important trend of world railway development. The central task of advancing the development of railway science is to improve the economic benefit. By the end of 2016, the length of railways in operation in China has reached 124,000 kilometers, and the high-speed railway has reached 22,000 kilometers. High-speed railway is an important part of national economy and is the main artery of social development.

1.1 Development status and market demand analysis of China's high-speed railway

Along with the sustained and rapid development of social economy, consumers' demand for high-speed railway passenger transport shows a rapid growth trend, and has the characteristics of diversity, which puts forward higher requirements for the development of high-speed passenger transport in China. The rapid development of modern logistics puts forward higher and newer requirements for railway transportation industry. However, due to the factors of the railway industry, the freight transport shows the characteristics of poor timeliness, low level of accuracy and incompatibility, and there is not suitable between the transportation capacity and demand. Therefore, it is urgent to make full use of the transport capacity of existing railways and seek new economic growth points to improve economic efficiency.

1.2 Analysis of constraints factors hinder the development of high-speed railway

The large scale of China's high-speed rail system, which is burdened with heavy operating tasks and operating and maintenance costs, will bring problems to the operation department and restrict the development of high-speed rail.

1.2.1 Dynamic dispersion, not unified industrial platforms, the high cost of operation and maintenance

In China, there are multiple technology platforms and as many as 14 series of the EMUs. There are many differences among each technology platforms' main systems, reflecting in the repair system and procedures, quick wear part and other aspects. These differences bring about great inconvenience to the management of operation organization, interconnection and maintenance. At the same time, the operating EMUs are all dynamic dispersion, resulting in a 25% reserve rate of the EMU. What' s more, with high manufacturing requirement, the space for further cost-cutting is extremely limited.

1.2.2 The EMUs has the disadvantage of function single, insufficient capacity and poor comfort

(1) The traffic density of busy roads tends to be saturated, and the capacity is not suitable to the demand

The traffic density of busy railway in China is large, and even some EMUs start at the same time. It is extremely difficult to increase the number of EMUs.

(2) Poor adjustment ability and single transportation function

The existing EMUs with single-layer design have low transport capacity, and both of them are dynamic dispersion and integral train. Even in the off-season, the whole EMUs have to be run, leading to an increase in unnecessary expenses. And it cannot realize the fast cargo transportation as well.

(3) The comfort level is not high

Most of the EMUs' are seats, and the long ride makes passengers feel tired, which leads to the low attendance rate of the long-distance railway. And the existing EMUS' berths have no private space for passengers. Because of the berth is arranged horizontally along the vehicle body, the passengers' instinctive defense ability is weak and the security is not good when emergency occurs.

All in all, the waste of resources is serious and cannot meet the passenger demand. The industrialization platform of 3X and its series of EMUs have emerged in this context.

2 Functional Advantages and Typical Marshalling

3X series EMUs will promote the standardization, serialization and unification of EMU in China. Its functional advantages and typical marshalling are introduced as follows:

2.1 Functional advantages

2.1.1 Progressiveness

Through the design of modular, serialized and humanized innovation, we build a completely innovative and unified technical platform of the different speed grades of 160-350km/h and 2-16 variable marshalling groups. Innovative design of new models to meet the needs of different transportation routes such as long, medium and short distances; Also it has new functional facilities innovation.

2.1.2 Reliability

The new series EMUs realize the integration of unit power, adopt mature network structure and hardware configuration, reduce train power and control wire, improve stability and reliability; The single motor vehicle is equipped with full power configuration, which can be removed when fails.

2.1.3 Comfort

The sleeper has independent space, tea table, film and television system, improves the privacy and comfort. The business car designed a rotatable business seat to meet the passenger's multi-directional needs; the back seat is used in intercity trains to ensure the same direction between seats and driving; First class seat add leg function to improve ride comfort.

2.1.4 Economy

The reserve and replacement maintenance are realized, and the detection rate can be reduced by 50% compared with the existing EMUs. The average number of cities increased by more than 50%. The per capital energy consumption of EMU decreases by more than 40% compared with the same type EMU.

2.2 Introduction of typical marshalling

2.2.1 Long distance marshalling scheme

(1) Plan A: long distance, 16 double-layer vertical full-sleeper EMU.

The new 16 double-layer vertical full-sleeper EMU have a crew of 60, complete with 900 passengers and 22m or 6t goods. This type of EMU can be operated at 200-350km/h and can connect the journey of 1,500-2,500km to meet the passenger's requirement for comfort. In addition, these kinds of EMU can save the accommodation cost for the passenger, and will be favored by the vast number of travelers. Therefore, the passengers with the long distance travel at night could choose plan A.

Plan B: long-distance, 16 single-layer sleeper and double-decker business class EMU.

The new 16 single-layer sleeper and double-decker business class EMU complete with 900 passengers (the number of sleepers, business seats and the restaurant seats are 440,128 and 40 respectively, 22m or 6t goods); If the sleeper is converted to the first class seat and, the EMU can contain 1048 people. This type of EMUs can satisfy the requirement of the comfort of the long-term passengers, and also meet the demand of the larger passenger flow on the short–distance. Therefore, the passengers with the long distance travel during the daytime could choose plan B.

2.2.2 Medium distance marshalling scheme

Plan C: medium distance, weekend mode, 16 single-double layer mixed with full-seat EMU.

There are two typical marshalling scheme on the middle distance railway: first, the total number of the EMU is 1,259 (288 business seats, 931 second-class seats, 40 restaurant seats, 22m or 6t goods). This type of EMU considers the long-distance travel of business people, who are not sensitive to the ticket price, but has a higher requirement for comfort level. This type of EMU can be operated on Monday morning, Friday and Sunday afternoon. Second, the total number of the EMU is 1,575 (8 business seats, 56 first-class seats 1,471 second-class seats, 40 restaurant seats, 22m or 6t goods). This type of EMU considers the travel needs of students, general commuters, family visitor and tourists, who are more sensitive to ticket prices, and can be operated except Monday morning, Friday

and Sunday afternoon.

2.2.3 Short distance marshalling scheme

Plan D: Short distance, weekend mode, single-double layer mixed with full-seat EMU.

There are two typical marshalling schemes on the short distance railway: first (short distance, 5+5 marshalling single-double-layer hybrid urban train), the total number of the EMU is 1906 (986 second-class seats, 920 standing tickets). This type of EMU can be operated on Monday morning, Friday afternoon, Saturday and Sunday as much as possible to meet the passenger's demand during peak hours. Second (short distance, the eight marshalling single-double deck mixed with the full car), the total number of the EMU is 696 (8 business seats, 28 first-class seats, 619 second-class seats, 40 restaurant seats, 22m or 6t goods), and can be operated except Monday morning, Friday afternoon, Saturday and Sunday.

3 Economic Benefit Analysis

This paper using the cost savings (such as variable marshalling etc.) and income increases (mainly the high speed rail lines, based on the classification of different types of quantitative yields) to analyze the economic benefit bringing by 3X series EMU industrialization platform respectively.

3.1 Economic benefit analysis (cost saving) of the industrialization platform of the 3X series EMUs

3.1.1 Design features of the industrialization platform of 3X series EMUs.

The industrialization platform of the 3X series EMUs is a good platform for universal property. Firstly, as a unified industrial platform, it can save the cycle of design and verification and improve reliability and safety in production and manufacturing. The main system components are generality, which can greatly improve the production and maintenance efficiency of the EMUs. Secondly, 3X series EMUs is a dynamically centralized variable marshalling train, which means the power distribution of the EMUs is at both ends of the train, the power unit configuration of the train is identical at head and tail, to avoid all scheduled outages caused by temporary repairs, reduce the cost of vehicle purchase.

3.1.2 The cost-saving analysis of the industrialization platform of 3X series EMUs.

(1) Power concentration, variable marshalling, reduce the inspection rate, and save cost vehicle purchase.

①The analysis of the condition of the EMUs.

At present, the EMUs need an advanced repair cycle completed in eight years. Each year, primary and secondary maintenance should be carried out 30 times, including 24 maintenance cycles of one day, four maintenance cycles of two days, two maintenance cycles of three days, totally 38 days. There are about 20 kinds of temporarily service. At least nine visits to each train every year, two days on average.

Table 1 Maintenance Cycle

Class of Repairs Operation	3-level repair	4-level repair	3-level repair	5-level repair
Distance (Ten thousand km)	120	240	360	480
Maintenance time (day)	35	70	35	90

According to the maintenance cycle of EMUs, the following table is shown in the 2,000 columns:

Table 2 The spare number of EMUs

Class of Repairs Operation	Number of spare	Proportion (%)
Repair turnover	100	5.0

1 and 2-level repair turnover	208	10.4
3, 4 and 5-level of repair turnover	170	8.9
Total	487	24.3

②Analysis of the inspection readiness of the series of 3X series EMUs

Table 3 The number of high level maintenance units

Kind of Class	Class of Repairs Operation	High Level repair cycle (day)	Annual maintenance quantity	Repairing frequency	The Spare Number of High Level repair	The amount that needs to be increased caused by the gap between power unit and trailer overhaul cycle
Tow Truck	3-level repair	15	500	0.64	23	—
	4-level repair	30	250	1.28	23	—
	5-level repair	40	250	1.28	31	—
	Total				77	—
Power unit (2 groups per emu)	3-level repair	35	500	0.64	54	30
	4-level repair	45	250	1.28	35	10
	5-level repair	60	250	1.28	46	14
	Total				135	54

The average operation time of 3X EMUs can be shortened to one day by replacing vehicles. The number of spare vehicles is 50% of the total number of reserved vehicles, i.e., the number of primary, secondary maintenance and temporary repair reserve number of 2,000 3X series EMUs is 7.7%. The standby ratio of the 2,000 3X series EMUs =7.7%+6.55%= 14.25%.

③ Saving vehicle purchase cost = 24.30%*2000* 2.02-14.25% *2000*1.62=520 (billion).

(2) The total cost savings of the industrialization platform of the 3X series EMUs statistics as follows:

Table 4 Total cost savings of 3X series EMUs industrialization platform

Projects	The cost savings by current 2,000 EMUs	The cost savings are expected by 3,500 EMUs in 2020	The cost savings are expected by 5,000 EMUs in 2025
Spare car (25% original plan, 15% new scheme)	300	525	750
Reduce procurement costs	360	630	900
Reduction of depreciation(5%)	18	31.5	45
Reduction in inspection fee (8%)	18	31.5	4
Annual reduction of salary	0.08	0.14	0.2
Total (Billion Yuan)	396.1	693.1	990.2

3.2 Income analysis of the series of EMUs in the industrial platform of 3X (increase

revenue)

3.2.1 Calculation example analysis

Taking the year of 2017 as an example. Monday, Friday and Sunday are 52, 52 and 53 days respectively. This section selects Beijing-Guangzhou high-speed rail line, from the improvement of 3X the EMUs, with different models to classify the direct economic benefits of high-speed operation of quantitative analysis, to analyze its market competitiveness. The development plan of the Beijing-Guangzhou railway train can be selected according to the time duration among different stations, as shown in Table 5.

Table 5 The time consuming and the plan selections of the Beijing-Guangzhou high-speed railway stations

Interval	The length of time (h)	Plan selections
The EMUs during the day		
Beijing-Guangzhou	9.5	B
Shijiazhuang-Guangzhou	8.5	B
Zhengzhou-Guangzhou	6.5	B
Wuhan-Guangzhou	4	C
Changsha-Guangzhou	3	C
Beijing-Shijiazhuang	1.5	C
Beijing-Zhengzhou	3	C
Beijing- Wuhan	5	C
Beijing-Changsha	6.5	B
Sleeper EMUs during the night		
Beijing-Guangzhou	11h	A

Assuming that the EMUs are full in 2017, the total income is summarized as following:

Ticket revenue = $\sum_{t=1}^{n} P_t \times Q_t$ * N (P: ticket price, Q: capacity, N: open ranks number) (formula Ⅰ)

Freight revenue = each operation train * single interval freight revenue (formula Ⅱ)

Table 6 Revenue summary (Billion Yuan)

	Type	Capacity	Ticket revenue	Freight revenue	Increased income
The original type of EMUs	Ordinary intercity trains	1,061	256.05	0	215
	Sleeper EMUs	630	15.66		
The new type of EMUs	Sleeper-Seat transformation	1,048	170.90	17.51	
	Sleeper EMUs	900	24.17		
	16 single double-layer mixed all-seat vehicle marshalling	1,259	298.30		
	The middle distance of 16 single-double deck mixed with the whole vehicle marshalling	1,575			

At present, the proportion of the direct tickets to Guangzhou is less than 5%, while the moving

sleeper can be sold out, so the increase of income will be higher in the actual operation.

3.2.2 The total revenue of the main railway lines and short-distance inter-city lines in China

According to the above typical case analysis, the train of the proper formation will be operated to the specific high-speed railway line. The specific results are as follows:

Table 7 Total revenue summary of saturation of passenger flow line

Name of high-speed railway	Original EMUs Ticket revenue (Billion Yuan)	New EMUs Ticket revenue (Billion Yuan)	New EMUs Freight revenue (Billion Yuan)	Increased income (Billion Yuan)
Beijing-Shanghai	256.67	360.11	12.64	116.08
Beijing-Harbin	171.65	260.97	16.47	105.79
Beijing-Guangzhou	271.71	486.71	17.51	215
Shanghai- Shenzhen	151.67	222.92	21.44	92.69
Shanghai-Kunming	181.50	266.19	9.62	94.31
Shanghai-Chongqing	180.72	276.92	19.45	206.65
Xuzhou-Lanzhou	110.78	187.56	8.32	85.1
Qingdao-Taiyuan	96.45	167.87	7.77	79.19
Beijing-Tianjin	17.50	27.97	2.88	13.35
Shanghai-Nanjing	29.20	47.65	2.22	20.67
Guangzhou-Shenzhen	32.93	46.71	4.01	17.79
Guangzhou-Zhuhai	28.89	37.01	3.33	11.45
Guangzhou-Foshan	8.46	10.85	-	2.39
Dongguan-Huizhou	8.27	11.69	-	3.42
Wuhan-Huanggang	0.18	0.22	0.15	0.19
Wuhan-Xianning	0.82	2.51	-	1.69
Wuhan-Xiaogan	1.10	1.36	0.67	0.93
Changsha-Xiangtan	10.71	10.87	0	0.16
Guiyang-Kaiyang	0.42	1.28	-	0.86
Nanchang-Jiujiang	2.33	7.15	-	4.82
Changchun-Jilin	2.73	8.33	-	5.6
Qingdao-Rongcheng	1.49	3.21	0.52	2.24
Zhengzhou-Jiaozuo	2.01	3.78	0.47	2.24
Zhengzhou-Kaifeng	0.75	2.25	-	1.5
Nanjing-Anqing	2.23	6.92	0.46	5.15
Liuzhou-Nanning	0.85	4.31	0.09	3.55
Lanzhou-Zhongchuan	1.08	3.29	-	2.21
Total	1,573.1	2,466.61	128.02	**1,095.02**

3.3 Prediction of long-term economic benefit in high-speed railway

At present, the number of EMUs in China is 2,000. By year 2020 to 2025, China's high-speed railway will reach 30,000 and 38,000 kilometers respectively, and the number of the EMUs will reach 3,500 and 5,000 columns. Between the year of 2008 and 2015, the average annual growth rate of passenger was 10.48%. With the matured of technology, the demand for high-speed rail will be further improved. Therefore, the growth rate of the trend of

national railway line in 2015 to 2025 is expected to increase steadily to more than 10.48% (this paper is conservative in this proportion). The formula is as follows:

The total return of railway forward economy (formula Ⅲ) = *trend passenger flow * fares + freight revenue*

This part of the passenger flow presents a continuous and gradual growth trend, which manifests itself as an orderly and bounded sequence. Therefore:

The total revenue of high-speed railway in 2020 = High-Speed Railway ticket income in 2017* (1 + passenger traffic growth rate) ^{3} * (new mileage/original mileage) + freight revenue in 2017 * (2020 EMUs ownership in 2020/ 2017 EMUs ownership) * (new mileage/original mileage) = 4,841.26 (million Yuan)

In accordance with the above formula, it will achieve more than RMB1 billion in revenue in the year 2025 if a new type of train on the main high-speed rail line is full.

3.4 The analysis of overall income

Based on the cost saving statistics table above, assuming that the passenger seat rate and freight capacity of the new train are 40%, 60%, 80% of the new revenue and the cost savings are shown in the following Table 8:

Table 8 New revenue and cost-saving statistics of new type 3X high-speed trains for passenger seats

Year	Saving Cost	Attendance Rate	Increased Income (Billion Yuan)	Total Increased economic benefits (Billion Yuan)
2017	396.1	80%	876.02	1,272.12
		60%	657.01	1,053.11
		40%	438.01	834.11
2020	693.1	80%	1,855.54	2,548.64
		60%	1,391.66	2,084.76
		40%	927.77	1,620.87
2025	990.2	80%	3,800.73	4,790.93
		60%	2,850.55	3,840.75
		40%	1,900.36	2,890.56

4 Conclusions and Prospects

High-speed railway will gradually become the mainstream transportation tool for people. And the industrial platform 3X series EMU can realize fast freight, and the cold chain transportation on the health care industry and national economy and people's livelihood also bring great convenience. The 3X series EMU is a railway product which adapts to national conditions and railway development prospect.

Firstly, high-speed rail could enhance the strength of high-speed rail service and the passenger's satisfaction, to attract potential passengers and increase the demand for high-speed rail. Secondly, high-speed railway should actively cooperate with e-commerce logistics to expand the express delivery market. Finally, according to the passenger flow composition design the train marshalling. High speed railway should be combined with the above three aspects to rebuild transport organization mode, and make full use of the advantages of science and technology to create greater economic benefits.

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