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Research on Public Transport Construction Satisfaction based on Structural Equation Model

-- Take Tianjin as an Example

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Abstract

Passenger satisfaction plays a key role in the sustainable development of public transport. Taking the construction of public transport in Tianjin as an example, this article analyses passenger satisfaction in the process of waiting and riding through field research and questionnaires, and establishes a structural equation model based on passenger information, comfort, intelligence, convenience and accessibility. The analysis path was created and validated using AMOS 24.0, which showed that comfort, intelligence, convenience and accessibility have a positive impact on satisfaction with public transport construction, in decreasing order of importance. Based on the results of the analysis, in the process of urban public transport renewal, it is recommended to optimise ride experience purposely, at the same time, meeting the needs of different passengers by optimising facilities, so as to improve passenger satisfaction.

Keywords

Tianjin; Public Transportation Construction; Satisfaction Degree; Structural Equation Model; Public Transport.

1. Introduction

The 21st century has seen a rapid increase in private car ownership, along with rapid urbanisation and a significant rise in living standards. However, under the background of increasing depletion of soil sources and a large amount of pollution and traffic pressure caused by private cars, it is destined that private car-oriented development model will not last forever. By actively promoting the development of public transport could the problems such as traffic congestion and environmental pollution be improved effectively. Therefore, in the “13th Five-Year Development Outline for Urban Public Transport” promulgated by the Ministry of Trnasport in July 2016, stating that it is necessary to strengthen the construction of urban transport facilities and give priority to the public transport ("Notice of the Ministry of Transport on the Issuance of the "13th Five-Year Plan" Development Outline for Urban Public Transport_State Council Departments and Agencies_Chinese Government Website", 2022). As an important part of urban public transport, improving the level of bus services can attract more people to use public transport. However, the current development of public transportation is relatively lagging, and it cannot fully meet the travel needs of the public. The lack of some hardware facilities and poor ride experience have led to insufficient public transport attractiveness.

The study took Tianjin as an example, and took public transport passengers as the main subject. By collecting the satisfaction evaluation of public transport construction from people of different age, occupation, income and other characteristics, analysing passengers' evaluation of comfort, convenience, accessibility and intelligence during the time of waiting and riding, and establishing the correlation between different factors on comprehensive satisfaction by building a model, then finally proposed methods and approaches to improve the satisfaction of public transport construction.

The questionnaire questions were designed based on the Observable variable approach of the model constructed for this study. The researchers have developed their research on the satisfaction of public transport construction through different directions. Shanshan Li conducted a study on the satisfaction of public transport passengers through the tangibility, convenience, safety and reliability of public transport facilities (Li, S.S., 2016); Jie Meng studied the level of satisfaction with the use of urban public transport through five aspects: convenience, promptness, punctuality, comfort and economy (Meng, J., 2012). Changxu Peng conducted a survey on the satisfaction of public transport in Yichang City by investigating the safety, economy, accessibility, service attitudes of the staff, and the completeness of the information intelligent facilities of the public transportation system in the ride experience (Peng, C., 2013). Zhiqiang Zou 's research analysed satisfaction with the public transport experience through waiting time, transfer convenience, service attitude, station information service, ride comfort, punctuality, economy, travel speed and safety (Zou, Z., 2018). When evaluating urban transit satisfaction, there are many different perspectives. Maria Grazia Bellizzi evaluated it in terms of waiting and riding times, usage, fares, cleanliness and safety (Bellizzi, M. G. et al., 2020); besides Erik Bjørnson Lunke from the perspective of the distance to public transport stops, transfer modes and transfer waiting times; Yanan Gao from reliability and rapid responsiveness of bus operations (Gao, Y. et al., 2018); Ummi Aqilah Khalid from frequency of departures, operating time range and delays (Khalid, U. A. et al., 2014); and Jesper Bláfoss Ingvardson from network coverage, speed and frequency of trips, and fares and norms (Ingvardson, J. B. et al., 2019).

Summarizing the existing research results of the above scholars, the research factors are mainly concentrated in the aspects of convenience, accessibility, economy, etc. However, with the development of society and the popular use of mobile devices, services such as mobile payment and intelligent information enquiry are becoming more and more popular among passengers and have a certain degree of influence on the passenger experience, therefore the evaluation dimension adds intelligence to the previous studies.

2. Research Design

2.1 Study Area and Data Sources

Tianjin is one of the four central municipalities in China, as well as one of the economic and financial centres of mainland China, and is typically representative for studying satisfaction with public transport construction in first-tier cities. The questionnaire survey for this study covers the central city of Tianjin (Heping District, Nankai District, Hongqiao District, Hedong District, Hexi District and Hebei District), the four districts around the city (Xiqing District, Beichen District, Jinnan District and Dongli District), and the suburban districts (Wuqing District, Baodi District, Jinghai District, Binhai District, Jizhou District and Ninghe District) ("Administrative Divisions_Tianjin.gov", 2021).

The questionnaire was placed online and collected from June 1, 2020 to June 30, 2020, during which a total of 500 questionnaires were distributed, of which 486 valid questionnaires were returned, with an overall questionnaire efficiency of 97.2%. The Tianjin Public Transport Construction Satisfaction Evaluation Questionnaire consists of two parts: basic information about the sample and survey questions.

2.1.1 Sample Basic Information

The sample information included gender, age, region, education, occupation, annual per capita household disposable income, whether or not they owned a private car and their usual means of transport (Table 1). Among the surveyed population, 49.3% were male and 50.7% were female; 0.6%

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were under 18 years old, 27.2% were between 18 and 26 years old, 44.6% were between 27 and 43 years old, and 5.4% were over 61 years old; 35.0% were located in the main city centre, 15.3% in the four districts around the city, and 49.7% in the remote suburbs; 9.6% were educated at high school or below. 49.7%; 9.6% had high school or less education, 20.1% had college education, 44.9% had bachelor's degree, 17.1% had master's degree or master's degree, 8.4% had doctoral degree or doctoral degree; 5.4% were government officials, 68.3% were teachers and students, 16.2% were employees of enterprises, and 16.2% were freelance workers. 16.2%, freelance workers and others 7.2%; the annual per capita disposable household income was below RMB10,000 (36.5%), between RMB10,000 and RMB30,000 (27.2%), between RMB30,000 and RMB50,000 (13.5%), between RMB50,000 and RMB70,000 (10.5%) and above RMB70,000 (12.3%); public transport accounted for 29.9%, private cars accounted for 38.0% and taxis accounted for 5.0%. 38.0%, taxis accounted for 5.4%, bicycles and walking accounted for 25.4%, and car sharing accounted for 1.2%.

The age, location, educational background, occupation, per capita disposable income of the family, commonly used means of transportation and whether owning private cars in the sample information provide measurement reference indicators for judging whether the questionnaire is scientific, accurate and representative (Wang, H., 2015).

Table 1. Basic information of the sample

Name	Category	Percentage	Name	Category	Percentage
Gender	Male	49.3%	Occupation	Government officials	5.4%
	Female	50.7%		Teachers and students	68.3%
Age	Under 18	0.6%		Enterprise staff	16.2%
	18-26	27.2%		Self-employed	3.0%
	27-43	44.6%		Freelancers and others	7.2%
	44-60	22.2%	Household disposable income per capita/year	Under RMB 10,000	36.5%
	Over 61	5.4%		RMB 10,000 - 30,000	27.2%
Location	Central city	35.0%		RMB30,000-50,000	13.5%
	Four districts around	15.3%		RMB50,000-70,000	10.5%
	Suburban districts	49.7%		Over RMB70,000	12.3%
Education	High School and below	9.6%	Common means of transport	Public transport	29.9%
	Junior college	20.1%		Private car	38.0%
	Undergraduate	44.9%		Taxi	5.4%
	Master	17.1%		Bicycle and walk	25.4%
	PhD	8.4%		Shared car	1.2%
Own private car or not	Yes	55.4%	--		
	No	44.6%			

2.1.2 Model Variables

The questionnaire (Table 2) was based on a five-point Likert scale in which respondents rated their level of satisfaction according to their waiting and riding experience: 1 for most satisfied or highest intensity; 2 for more satisfied or high intensity; 3 for just satisfied or average intensity; 4 for less satisfied or weak intensity; and 5 for very dissatisfied or very weak or none. The use of a five-point Likert scale in the questionnaire allows for better differentiation of satisfaction ratings while preventing skewed data (Zhang, B. et al., 2016).

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Table 2. Model variables and their assignment methods

Latent variables	Observable variable	Assignment methods
Comfort	Waiting experience	1.Very satisfied 2.Relatively satisfied 3.Satisfied 4.Relatively dissatisfied 5.Very dissatisfied
	Riding experience	
Convenience	Punctuality	
	Waiting tim	
	Operating hour	
Accessibility	Distance from departure to bus stop	
	Transfer distance	
	Distance from bus stop to destination	
Intelligence	Line enquiry	
	Arrival time enquiry	
	Payment method	
Overall satisfaction	Waiting process	
	Riding process	

2.2 Descriptive Statistics for Variables

The descriptive statistics of the questionnaire data variables are as follows (Table 3). The mean value of variable satisfaction is mainly distributed between 2.05 and 2.72, which can be divided into four levels. The variables whose mean distribution is 2.05-2.28 are: payment method, ride experience and punctuality rate. The variables whose mean value is distributed between 2.30 and 2.34 are: boarding process, waiting process and route query. The variables with mean distribution in 2.35-2.66 are: arrival time query, operating time and waiting experience. The variables whose mean distribution is in the range of 2.67-2.99 are: transfer distance, distance from departure point to bus stop, distance from bus stop to destination and waiting time.

Table 3. Descriptive statistics of variables

Observable variable	Minimum	Maximum	Average	Means sorting	Standard deviation
Waiting experience	1	5	2.38	9	0.941
Riding experience	1	5	2.27	2	0.897
Punctuality	1	5	2.28	3	0.945
Waiting time	1	5	2.99	13	0.829
Operating hour	1	5	2.36	8	0.941
Distance from departure to bus stop	1	5	2.67	11	0.976
Transfer distance	1	5	2.66	10	0.913
Distance from bus stop to destination	1	5	2.72	12	1.018
Line enquiry	1	5	2.34	6	0.902
Arrival time enquiry	1	5	2.35	7	0.910
Payment method	1	5	2.05	1	0.882
Waiting process	1	5	2.32	5	0.821
Riding process	1	5	2.30	4	0.838

3. Model Construction

The paper uses structural equation modelling (SEM) to conduct the analysis. Structural equation modelling (SEM) is a comprehensive statistical research method that combines variable analysis and path analysis, and can perform statistical analysis of multiple variables, so it is widely used in the analysis of various causal models (Wu, M., 2009).

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3.1 Questionnaire Validity and Reliability Analysis

To ensure the accuracy and reliability of the constructed model, validity analysis and reliability analysis were conducted on the questionnaire data before constructing the model. The validity of the questionnaire data needed to be verified by Bartlett's sphericity test and KMO values (Cheng, Q. et al., 2019). The results of the test are shown in Table 4. The significance of the questionnaire data was 0.000 and less than the reference value of 0.001, indicating that the requirements were met. In addition the Bartlett's spherical test on the questionnaire data showed a KMO value of 0.930, with a KMO value greater than the reference value of 0.60, indicating that the questionnaire data met the validity requirements of the model.

The questionnaire data reliability was verified by analysing the individual variables Cronbach's alpha by using the Cronbach's coefficient (Liang C. et al., 2015). According to the results of the analysis, the overall Cronbach's alpha was 0.945 and IT was greater than the reference value of 0.7, which proved that the reliability of the questionnaire data was good.

Table 4. Bartlett test and KMO value analysis

KMO sampling suitability number		0.930
Bartlett Sphericity Test	Approximate cardinality	500.794
	Freedom	175
	Significance	0.000

3.2 Model Construction

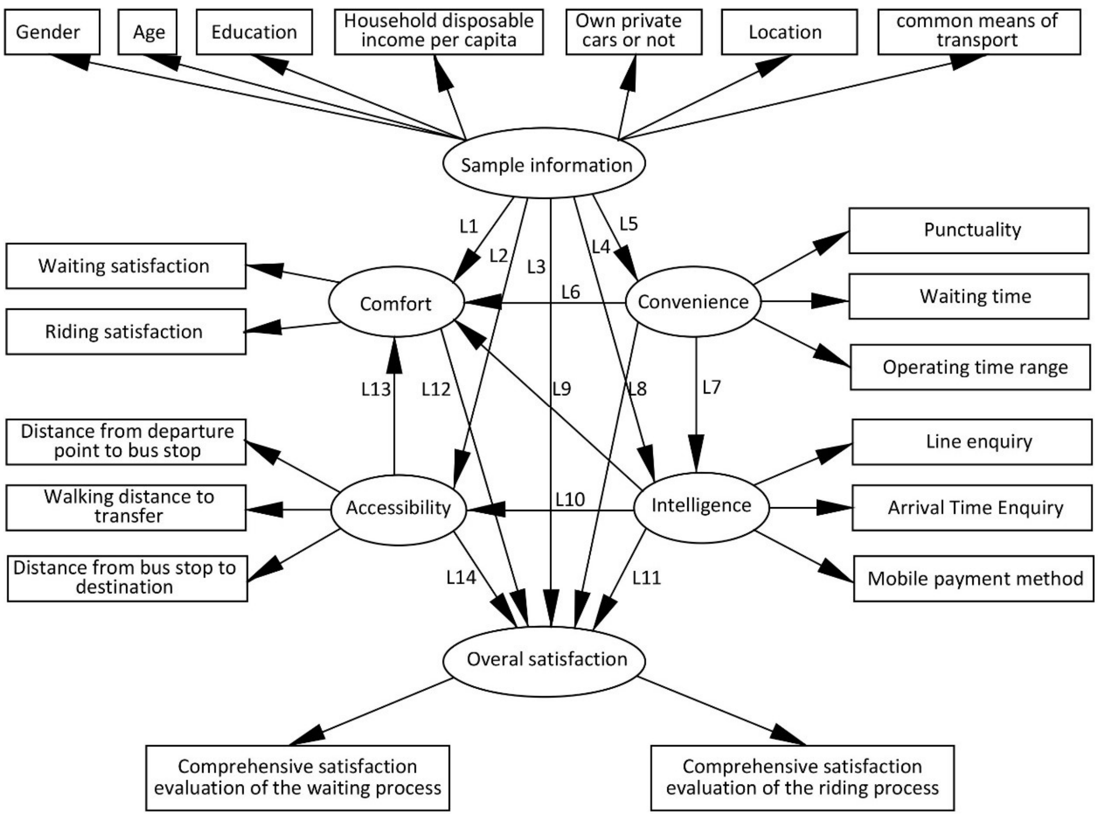

Figure 1. Hypothetical structural equation model

Based on the above theoretical analysis and questionnaire data as well as the analysis with relevant professional knowledge, the hypothesis of the correlation between the five latent variables and the overall satisfaction is proposed (Figure 1) as follows.

Comfort, accessibility, intelligence and convenience have a positive impact on overall satisfaction, while sample information has a negative impact on overall satisfaction. Convenience positively influences comfort, convenience positively influences intelligence, intelligence positively influences accessibility, intelligence positively influences comfort and accessibility positively influences comfort.

3.3 Model Correction

By plotting the structural equation model in AMOS 24.0 and analytically testing the hypothetical model fit, the model was tested by examining the x2/df, GFI (Goodness of Fit Index), CFI (Comparative Fit Index) and RMSEA (Root Mean Square Error of Approximation) (Shen, W. et al., 2015), and the results of GFI and CFI did not reach the recommended values, therefore the model needs to be revised. The paths that did not hold in the model were removed (Table 5) and the model was adjusted to form a new model, after which the following model parameters were obtained by rechecking the fit of the model (Table 6). From the actual fitted values of the model and the standard reference value, it was found that the model basic fit index x2/df was 1.209, which was less than the standard reference value of 5, proving that the revised model had a better fit. The approximate error indices RMSEA and SRMR were 0.075 and 0.059 respectively, which were both smaller than the standard reference value of 0.08, indicating that the modified model fit was better. The goodness-of-fit index GFI and the adjusted goodness-of-fit index AGFI were 0.936 and 0.979 respectively, both of which were greater than the standard reference value of 0.9, which were in line with the required range of parameters. The canonical fit index NFI, comparative fit index CFI and incremental fit index IFI of the model are all greater than the standard reference value of 0.9, indicating that the modified model has a good fit and the model validation is passed.

Table 5. Test results of the measurement model

Path number	Hypothetical path	Regression coefficient	Hypothesis testing
L_1	Sample Information → Comfort	-.09	Not Established
L_2	Sample Information → Accessibility	.10	Not Established
L_3	Sample Information → Overall Satisfaction	.02	Not Established
L_4	Sample Information → Intelligibility	-.02	Not Established
L_5	Sample Information → Convenience	-.21	Not Established
L_6	Convenience → Comfort	.98	Established
L_7	Convenience → Intelligence	.88	Established
L_8	Convenience → Overall satisfaction	.34	Established
L_9	Intelligence → Comfort	.02	Established
L_{10}	Intelligence → Accessibility	.76	Established
L_{11}	Intelligence → Overall satisfaction	.38	Established
L_{12}	Comfort → Overall satisfaction	.55	Established
L_{13}	Accessibility → Comfort	.02	Established
L_{14}	Accessibility → Overall satisfaction	.12	Established

Table 6. Various related fitting indexes after the model is revised

Fit index	x^2/df	RMSEA	OOSRMR	GFI	AGFI	NFI	CFI	IFI
Standard value	<5	<0.08	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Actual value	1.2096	0.075	0.059	0.936	0.979	0.915	0.912	0.913

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The modified structural equation model (Figure 2), through the regression coefficient of the model path and the T value test to test the significant significance of the path coefficient (Cao, C. et al., 2012), and finally obtain a qualified structural model.

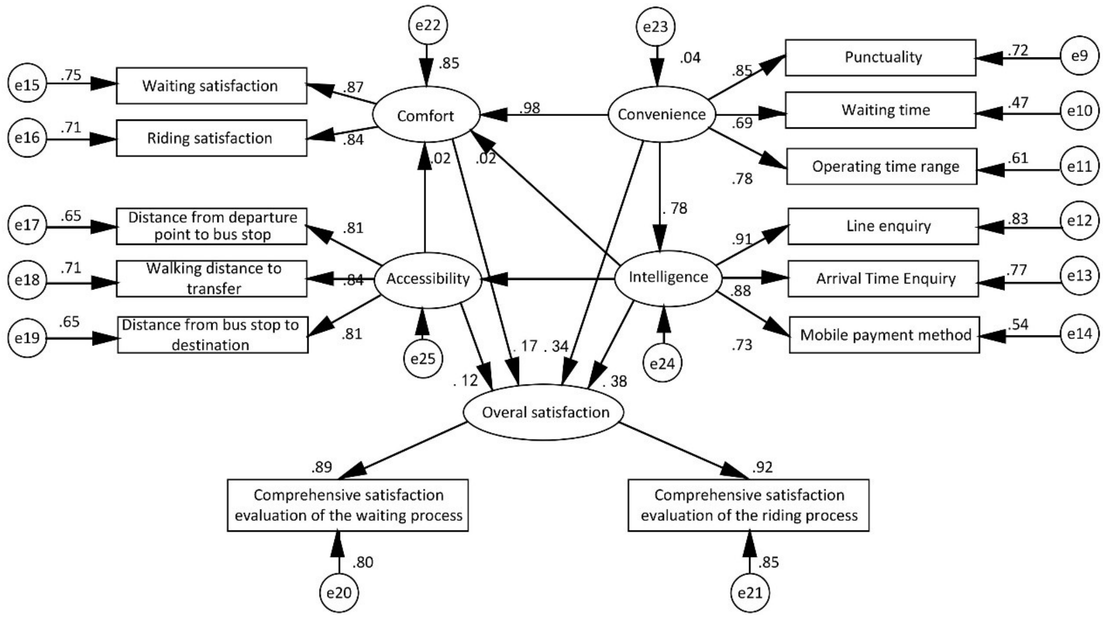

Figure 2. The final structural equation model

Table 7. Comprehensive table

Cause variable	Resulting variable	Total effect	Direct effect	Indirect effect	Sort
Convenience	Overall satisfaction	.902	.336	.566	3
Intelligence	Overall satisfaction	.398	.349	.049	4

Based on the results of the above causal model and test model (Table 7), it can be seen that all test values of the model meet the requirements, indicating that the adjusted model is reasonable. According to the direct and indirect influence relationship between the above latent variables, the following results are obtained:

Firstly, the total effect of satisfaction with the ride process and satisfaction with the waiting process on overall satisfaction in the model is 0.992 and 0.995 respectively, indicating that passengers are more concerned about the waiting experience. Of the five latent variables in the model, convenience, smartness, accessibility and comfort have a direct positive effect on overall satisfaction, while convenience and smartness have an indirect positive effect on overall satisfaction through comfort.

Secondly, the latent variables of convenience, intelligence, comfort and accessibility have a positive effect on the overall satisfaction and the total effects after standardisation are 0.902, 0.396, 0.165 and 0.128 respectively. Therefore, the factors to be paid more attention to in the renewal of public transport construction in Tianjin are: convenience, intelligence, comfort and accessibility respectively.

Thirdly, different observable variables have varying degrees of influence on latent variables. Among the convenience, the most significant direct effect is punctuality, followed by operating time range and waiting time. In terms of intelligence, the most significant direct effect is on route search, followed by arrival time enquiry and mobile payment methods. In terms of accessibility, the distance from the departure point to the bus stop has the greatest direct effect, followed by the walking distance required to transfer and the distance from the bus stop to the destination. In terms of comfort, the most significant direct effect is on the waiting experience, followed by the travelling experience.

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4. Conclusion

Taking the survey data of public transport construction satisfaction in 16 urban areas in Tianjin as an example, this study empirically analysed the influencing factors of urban public transport construction satisfaction, and constructed a structural equation model.

The results showed that the model has a good fit and that the model can be used to analyse which factors have a direct impact on satisfaction with urban public transport construction and which factors have an indirect impact on satisfaction with urban public transport construction through intermediate factors. In the actual public transport construction update, the data can be collected to obtain the actual needs of the public and optimise the construction of public transport in order to improve the satisfaction of public transport construction. Based on the results of this analysis, this paper makes the following recommendations for increasing satisfaction with public transport construction:

Firstly, in the waiting and riding experience, passengers pay more attention to convenience than other influencing factors. To improve the convenience of travel, we can start from the following aspects: first, to enhance the convenience of public transport transfer, such as reasonable arrangement of running time, and to enhance the rationality of the connection between public transport and urban road traffic, so as to facilitate passengers to transfer to the bus; the second is to shorten the waiting time of passengers; the third is to increase the speed of the vehicle under the premise of safety; the fourth is to ensure that the bus stops on time and departs on time. In addition, during peak periods such as Spring Festival and other holidays, flexible measures such as increasing the number of trains and extending operating hours should be used to meet the demand for rides, and at the same time, the frequency of departures and the interval time should be reduced during peak periods.

Secondly, with the popularity of the Internet of Things and mobile devices, the construction of a smart bus platform allows passengers to easily access bus ride information, displays real-time traffic operation information, and makes the best ride plan for passengers. Smart devices are also used to provide advisory services such as voice instructions and intelligent assistants for special needs groups, taking their demands fully into account and optimising hardware facilities in a timely manner. Meanwhile, additional mobile collection devices are installed in the buses and support mainstream payment platforms, making it easy for passengers to make cashless payments.

Thirdly, from the overall layout of the city, a reasonable distribution of bus stop density in the city centre areas such as the city's commercial centres and city parks where there is a high flow of people, thus facilitating residents to increase the number of bus stops close to them, effectively reducing the distance from the departure point to the bus stop and the bus stop to the destination, which can enhance the frequency of use of public transport. In addition, big data can be used to actively optimise transfer routes, reduce unnecessary transfers on key routes and reduce walking distances when transferring, thereby improving accessibility.

Fourthly, optimise bus hardware and facilities to enhance the comfort of the ride. Optimise bus hardware facilities for special needs groups, facilitate wheelchair access and optimise seats for special needs groups. Training for drivers and crew to improve service levels.

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