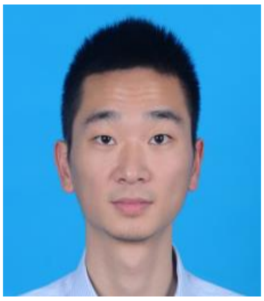
RESEARCH ON TEST METHOD AND EVALUATION SYSTEM OF PERFORMANCE OF SEMI-TRAILER TRACTOR






Chaozhi Huang
Engineer at China Automotive Engineering Research Institute Co., Ltd.

Lei Xu
Section chief at China Automotive Engineering Research Institute Co., Ltd.

Jinying Zhou
Director at China Automotive Engineering Research Institute Co., Ltd.

Jun Long
Deputy director at China Automotive Engineering Research Institute Co., Ltd.

Abstract
As a large-tonnage and heavy-duty vehicle, semi-trailer tractors have made tremendous contributions to China's highway long-distance freight. In order to systematically test and evaluate the performance of the semi-trailer tractor, a test and evaluation system for the semi-trailer tractor was constructed. On this basis, subjective and objective tests and user surveys were conducted on 5 competing vehicles in the domestic market. The results show that the evaluation system can better reflect the performance of semi-trailer tractors, and has certain reference significance for the product development of related vehicle manufacturers.
Keywords: Semi-trailer tractor,Test evaluation, Subjective and objective test, User survey

1. Preface

The trend of heavy-duty trucks and trains in China is obvious, and the semi-trailer market is developing rapidly. Since 2009, China has surpassed the United States to become the world's largest automobile producer and consumer [1]. The statistical bulletin of the development of the transportation industry in 2018 shows that in 2018, China had 13.5582 million trucks, including 237.067 million tractors, an increase of 14.7%, and 2.876 million trailers, an increase of 17.2% [2].

People pay more and more attention to the quality of semi-trailer tractor products. With the introduction of industry standards such as “Technical Conditions for the Safety of Operating Trucks Part 2: Traction Vehicles and Trailers” by the Ministry of Transport [3], and the implementation of road transport vehicle standard inspection, the semi-trailer market has gradually changed from a period of rapid development For the period of transformation and upgrading, the performance and quality of semi-trailer tractors are increasingly valued by people. Users can no longer satisfy only the basic needs of transporting more goods, more consideration is given to vehicle safety, economy, experience and other aspects when choosing a vehicle.

There is no unified and systematic evaluation system for the performance and quality of semi-trailer tractors in China. Existing national standards set minimum requirements for semi-trailer tractors from different management perspectives. Some semi-trailer tractor manufacturers also have their own evaluation systems, but the relevant evaluation systems all have deficiencies.

2. Construction of the Evaluation System

2.1 Research and Determination of Performance Indexes

China Automotive Engineering Research Institute has been building a commercial vehicle test and evaluation system since 2016. It has accumulated a large amount of data and formed a commercial vehicle evaluation database. We have conducted a large number of investigations on consumer concerns, demand points, complaints and complaints during the use of vehicles, and obtained a large amount of data. We have conducted visits and exchanges with a number of industry organizations, production companies, etc., and strive to accurately reflect the various performance levels of commercial vehicles. On this basis, China commercial vehicle evaluation regulations (semi-trailer tractors) have been constructed. The evaluation system includes four first-level indicators of driving safety, economy and efficiency, handling comfort and subjective experience. Cover 14 secondary indicators, as shown in Figure 1.

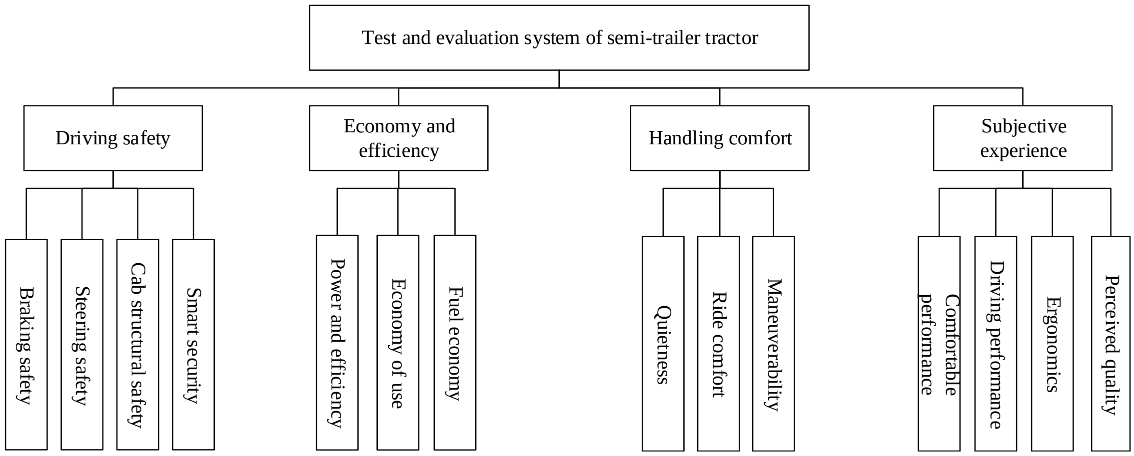


Figure 1 Test and evaluation system of semi-trailer tractor

2.2 Performance Index of Driving Safety

Safety has always been a top priority. Driving safety is the basic indicator of the evaluation system of semi-trailer tractors. This part mainly considers that the mass of semi-trailer trucks is large, prone to traffic accidents and often cause huge personal injuries and property losses. Driving safety includes four secondary indicators, which are based on the "human-vehicle-road" driving scenario to evaluate the active and passive safety of the vehicle, all of which are objective tests.

1) Braking safety. The braking problem is one of the main reasons in the traffic accident of the semi-trailer tractor. Therefore, the braking safety mainly evaluates the braking performance of the vehicle by evaluating the performance of the vehicle on the high attachment road, low attachment road and off-road road Including emergency braking, continuous braking, ABS braking, retarder braking and bend braking. Emergency braking is to simulate the full braking of the vehicle when it encounters an emergency. The evaluation index is the distance traveled when the vehicle brakes from 80km/h to 0km/h. Continuous braking mainly considers the thermal degradation resistance of the brakes of semi-trailer tractors under continuous downhill conditions. Most semi-trailer tractors use drum brakes, and serious thermal degradation is a common problem with drum brakes. Continuous braking is based on the German AMS brake test [4], braking at full speed to 0km/ h at 80km/h, accelerating to 80km/h at the fastest speed, and then braking to 0km/h, repeatedly Ten times, and finally, the average braking distance of the ten tests was used to evaluate the thermal degradation resistance. ABS braking mainly evaluates the ABS performance of the vehicle. The test method is that the vehicle is fully braked at an initial speed of 50km/h on the off road to a speed of 0 km/h. The evaluation index is the peak value of the vehicle's steering wheel correction in the first 2s. The retarder braking mainly considers the mass of the semi-trailer traction vehicle, the configuration of the retarder has become a trend, and the Ministry of Transport has put forward requirements on the relevant configuration [3]. The test method is to accelerate the vehicle to 70km/h, place the retarder in the gear that produces the maximum retarding performance, and taxi the vehicle to 40km/h. The evaluation index is the average braking deceleration of the vehicle. The bend braking mainly evaluates the curve braking stability of the semi-trailer tractor. The test method is to use the speed of 50km/h on a flat arc lane with an adhesion coefficient of less than or equal to 0.5, a radius of the centerline of the lane of 150m and a width of 3.7m Braking, to detect whether the vehicle deviates from the lane during braking.

2) Smart security. Intelligent configurations such as ESC, AEB, and LDW can effectively assist users in driving and improve vehicle stability. Relevant national departments have also forced or promoted the intelligent configuration of tractor installations in different time periods. Since only the high-end semi-trailer tractors currently have intelligent systems such as ESC, AEB, and LDW, the first stage of China 's commercial vehicle evaluation procedure (semi-trailer tractor) does not evaluate the performance of intelligent configurations such as ESC, AEB, and LDW To reflect its advanced nature in the form of bonus points. Intelligent safety covers ESC, FCW, AEBS, LDW,ACC, CCS, EBS, LCDA, Tire Pressure Monitoring Device, Tire Blast Emergency Safety Device, etc.
3) The structural safety of the cab. The structural safety of the cab mainly considers that the cab can better absorb energy and protect the occupant's safety in the event of collision, rollover and other accidents. According to ECE R29-03, the semi-trailer tractor adopts three items of double A-pillar impact test, top strength test and rear wall strength test [5]. Due to the destructive tests required for the structural safety of the cab, the first phase of the Chinese commercial vehicle evaluation regulations (semi-trailer tractors) will not be implemented for the time being.
4) Steering safety. Steering safety is mainly proposed based on the actual driving experience of the driver, and is evaluated through the steady-state rotation test. Generally, the vehicle needs to have certain understeer characteristics, and the understeer degree is calculated through the steady-state rotation test, and the understeer degree score is calculated according to "Automobile Handling Stability Index Limits and Evaluation Methods" (QC / T 480-1999) [6].

2.3 Performance Index of Economy and Transportation Efficiency

The semi-trailer tractor is a means of production, and its ultimate purpose is to be used for transportation operations. Users are generally concerned about its economy and transportation efficiency. Therefore, economy and efficiency cover three secondary evaluation indexes: fuel economy, Economy of use and power and efficiency. Fuel economy and power and efficiency are evaluated by objective tests, and Economy of use is evaluated by user surveys.
1) Fuel economy. Fuel economy includes two items: expressway fuel consumption and comprehensive operating conditions fuel consumption, which are comprehensively evaluated from both road and laboratory tests. expressway fuel consumption test method is that the semi-trailer tractor runs at a constant speed of 50km/h, 60km/h, 70km/h, 80km/h, 90km/h at a constant speed of 500m, and measures the fuel consumption at each speed, according to the weight Calculate the fuel consumption of the semi-trailer tractor on the expressway. The fuel consumption of comprehensive working conditions is to complete the C-WTVC cycle through the drum test. C-WTVC includes three cycles of urban cycle, highway cycle and high-speed cycle [7].
2) Economy of use. Economy of use as the research index, the survey sample size for each model is 100, and the areas are evenly distributed. The survey content mainly includes three aspects: reliability (failure rate), maintenance cost and user evaluation. Among them, the reliability (failure rate) is evaluated by the average failure rate of 100 vehicles, the maintenance cost is evaluated by the maintenance cost of 10,000 kilometers, and the user evaluation is evaluated by quality satisfaction and after-sales satisfaction, as shown in Figure 2.

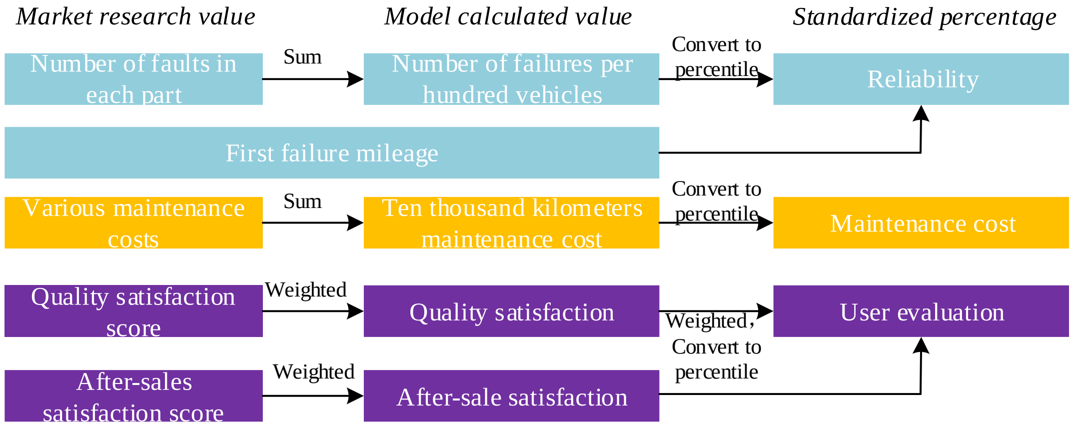


Figure 2 Survey of economy of use

3) Power and efficiency. The dynamic performance affects the transportation efficiency of the semi-trailer tractor. The power and efficiency mainly evaluates the acceleration of the vehicle, including two items of 0-40km/h starting acceleration and 60-100km/h overtaking acceleration. The evaluation index is acceleration time.

2.4 Performance Index of Handling Comfort

Due to the emergence of more and more young users, semi-trailer tractors are designed with more handling and comfort in mind than before to meet the needs of young users. Handling comfort includes three secondary evaluation indicators, handling, smoothness and quietness, all using objective tests.

1) Maneuverability. The maneuverability is mainly evaluated by two items: a serpentine test and a returnability test. The serpentine test can comprehensively evaluate the stability of the vehicle during the driving process. The vehicle travels around the pile at a speed of 60km/h, the pile spacing is set to 50m, and the evaluation index is the average peak yaw rate. The returnability test test mainly considers that the steering wheel of the semi-trailer tractor is heavy to avoid the driver's need to modify the steering wheel frequently due to road interference. The test method is to drive the semi-trailer tractor along a circle with a radius of 15m. After the lateral acceleration reaches (4 ± 0.2) m / s^2, fix the steering wheel angle for a period of time, then release the steering wheel to record the movement process. The evaluation index is the steering wheel residual angle when the steering wheel is released for 4s.

2) Ride comfort. Ride comfort mainly evaluates the vibration energy transmitted to the driver during the driving process of the vehicle, and is evaluated through two items of random input and pulse input. The random input test is to evaluate the performance of the vehicle when driving on a good road surface, and the pulse input test is to evaluate the performance of the vehicle when driving over convex or concave blocks. In the test, the vibration of the driver's seat above the seat cushion, the seat back, and the foot floor must be measured in three directions. The acceleration time history includes vertical (Z-axis) vibration, lateral (Y-axis) vibration, and longitudinal (X-axis) vibration. The evaluation index of the random input test is the maximum (absolute) acceleration Zmax of the driver's position, and the evaluation index of the pulse input test is the root mean square value av of the integrated total weighted acceleration.

3) Quietness. The quietness is mainly evaluated by the interior noise test when driving at a constant speed. The interior noise of the constant speed mainly considers the amount of noise the driver bears during the driving process. The noise may include engine noise, intake and exhaust noise, tire noise, wind Noise and so on. The noise test needs to use a sound level meter or an equivalent measuring instrument to measure the noise near the driver's ear when driving at 5 speed points of 60km/h, 70km/h, 80km/h, 90km/h, 100km/h at a constant speed , The evaluation index is A sound level.

2.5 Performance Index of Subjective Experience

Subjective experience is subjective evaluation or commodity evaluation. It is an important evaluation method widely used by major OEMs and technical service providers around the world. It aims to make a subjective perspective of all-dimensional evaluation of the attributes of the entire vehicle from the user's actual use and focus. In the entire evaluation system, the subjective experience can fully cover the aspects that cannot be measured objectively and close to the user, and it is also a second confirmation of the results of the objective test. The subjective experience includes four secondary indexes: perceived quality, ergonomics, driving performance, and comfort performance, of which perceived quality and ergonomics are static indicators, and driving performance and comfort performance are dynamic indicators.
The subjective evaluation borrowed from SAE J1060 ten-point evaluation standard [8], see Table 1., the rating scale is divided into three levels: "unqualified (cannot be produced)", "re-checked" and "qualified (can be produced)" according to the vehicle production recommendations. The corresponding quality and performance evaluations are "extremely poor" "very poor" "poor" "unsatisfactory" "minimum standard" "basically qualified" "medium" "good" "very good" "excellent" 10 grades, usually reaching the minimum standard line meets the vehicle listing requirements. Customer satisfaction is divided into 6 levels: "quite dissatisfied", "slightly dissatisfied", "satisfied", "more satisfied", "very satisfied", and "completely satisfied". Generally, do not reach areas of considerable dissatisfaction. Vehicles above 6 points (including 6 points) should be easy to drive, while vehicles below 5 points (including 5 points) are difficult or difficult to drive. It is difficult for a listed vehicle to reach 1 or 10 points. Usually, the score is concentrated between 4-9 points. In order to score more accurately, a minimum score of 0.25 can be given between 4-9 points.

Table 1 Subjective evaluation score criteria

Scoring criteria										
Evaluation score	1	2	3	4	5	6	7	8	9	10
Vehicle production recommendations	unqualified (cannot be produced)				re-checked	qualified (can be produced)				
Quality and performance evaluations	extremely poor	very poor	poor	unsatisfactory	minimum standard	basically qualified	medium	good	very good	excellent
Customer satisfaction	quite dissatisfied				slightly dissatisfied	satisfied	more satisfied	very satisfied		completely satisfied
People who want to improve	all customers			general customer		more discerning customers		trained testers		none

3. Test Vehicles and Equipment

3.1 Selection of Test Models

The researchers analyzed the sales data of 4 ×2, 6 ×2, and 6 ×4 semi-trailer tractors in the past 2 years, and then selected models with similar prices and configurations of different brands as the evaluation vehicles. In the end, five 6 ×4 semi-trailer tractors were selected as the evaluation models. See Table 2 for basic vehicle configuration information.

Table 2 Basic information of test vehicle

Serial number	Brand	Drive type	Engine power range	Gearbox range	Emission Standards	Vehicle price (ten thousand yuan)
1	A	6×4	540~560	12~14	National-V	36～40
2	B	6×4	540~560	12~14	National-V	36～40
3	C	6×4	540~560	12~14	National-V	36～40
4	D	6×4	540~560	12~14	National-V	36～40
5	E	6×4	540~560	12~14	National-V	36～40

3.2 Main Test Equipment

1) VBOX 3i. VBOX 3i is a product developed by Racelogic in the UK. It uses a powerful GPS engine, which can collect all GPS parameters including speed, heading angle and position. The sampling frequency can reach 100Hz.
2) RT3002 gyroscope. The RT3002 gyroscope is a product of British Oxts company. It has three acceleration and three angular velocity sensors and a GPS receiver, which are used to measure the acceleration and angular velocity of the vehicle in the x, y, and z directions. The test should ensure that the gyroscope is fixed and there is no relative movement with the vehicle body.
3) Steering wheel force and angle meter. The force and angular displacement signals are converted into electrical signals by a force-measuring mechanism sensor and an angular displacement sensor to measure steering wheel steering force and steering angle.
4) Ride comfort test and analysis equipment. Adopt German imc test equipment, mainly including 32-channel high-performance data acquisition equipment, three-axis cushion and backrest acceleration sensor, single-axis floor acceleration sensor, vehicle speed sensor, driving assistance display, etc.
5) Chassis dynamometer. The test road surface is simulated by the roller, the test road simulation equation is calculated, and the load is simulated by the loading device, which can be used for laboratory testing of vehicles under various working conditions.
6) Fuel consumption meter. Adopt German Gregory company test equipment, its measuring range is 0-120L / h, and the accuracy can reach 0.5%.
7) Sound level meter. Adopt the testing equipment of Danish B & K company, its range is 20-140dB, and the accuracy can reach 0.25dB.

4. Test Results and Analysis

4.1 Objective Test

Objective tests mainly include emergency braking, continuous braking, ABS braking, retarder braking, bend braking, steady-state rotation, expressway fuel consumption, comprehensive operating conditions fuel consumption, and 0-40km/h start acceleration, 60-100km/h overtaking acceleration, serpentine, returnability, pulse input, random input, interior noise of the constant speed, etc.

Table 3 Objective test data

Test items	Evaluating index	A	B	C	D	E
Emergency braking	Braking distance (m)	66.44	70.35	71.08	68.39	72.95
Continuous braking	Average braking distance (m)	45.11	55.03	52.71	52.76	59.05
ABS braking	Peak value of average steering wheel angle in the first 2s (°)	81.75	61.83	76.27	82.30	70.94
Retarder braking	Mean value of average deceleration (m / s^2)	-	2.33	0.68	-	-
Bend braking	Yes / no lane departure	no	no	no	no	no
Steady-state rotation	Understeer score	87.90	89.11	95.02	93.07	94.69
Expressway fuel consumption	Fuel consumption value (L / 100km)	39.91	40.87	37.00	36.88	38.61
Comprehensive operating conditions fuel consumption	Fuel consumption value (L / 100km)	43.57	45.19	43.84	44.57	44.69
0-40km/h start acceleration	Acceleration time (s)	19.19	16.03	16.26	18.49	18.74
60-100km/h overtaking acceleration	Acceleration time (s)	53.74	43.12	48.04	42.76	47.90
Serpentine	Peak value of average yaw rate (°/ s)	10.12	8.88	9.73	9.13	8.09
Returnability	Steering wheel residual angle (°)	51.46	33.04	20.66	11.05	22.90
Pulse input	Zmax (m/s^2)	3.45	7.13	7.39	9.59	7.74
Random input	av(RMS)(m/s^2)	0.22	0.20	0.19	0.25	0.21
Interior noise of the constant speed	Noise value (dB)	71.56	71.81	70.69	64.37	71.49

As can be seen from Table 3, The braking performance of the 5 vehicles is more uniform. Vehicles with good braking performance have shorter emergency braking and continuous braking distances. Regarding ABS braking, the Vehicle B performed the best and the Vehicle D performed the worst. Only two of the five vehicles are equipped with hydraulic retarders, and the performance of the Vehicle B is significantly better than the Vehicle C. Regarding corner braking, none of the five vehicles exceeded the lane boundary under full load. In the steady-state rotation test, all 5 vehicles have good understeer characteristics and the difference is not big. The fuel consumption of expressway and the comprehensive operating conditions of the five vehicles are relatively uniform. The fuel economy of the Vehicle B is the worst under the two operating conditions, and the Vehicle C performs better under the two operating conditions. In the expressway fuel consumption test, the maximum gap reached 4L / 100km. In the acceleration test, the start acceleration time of 0-40km/h of the five vehicles is not much different, and the overtaking acceleration of 60-100km/h shows a clear gap. The Vehicle D is more likely to overtake and change lanes in actual conditions. In the serpentine test, the peak value of the average yaw rate of each vehicle at the speed of 60km/h is within the acceptable range, and it is relatively stable during driving. In the steering-back test, the steering wheel's residual angle difference after releasing the steering wheel for 4s is obvious, and it is easier for the Vehicle D to return to the straight-line driving state. In the ride comfort test, the difference in pulse input performance of the 5 vehicles is relatively large. Vehicle A has the least impact on the driver when passing the speed bump, and the random input is not much different. In the constant speed vehicle interior noise test, the vehicle D has the lowest noise, and the other vehicles have little difference.

4.2 User Research

1) Research content and research objects

User research is mainly to use economic research, including the failure rate of a hundred vehicles, the mileage of the first failure, the maintenance cost of 10,000 kilometers, quality satisfaction and after-sales satisfaction. In user research, the research objects must be vehicle owners and drivers, and the vehicle age should be within 2 years. The number of samples for each model is 100, and the sample area is evenly distributed.

2) Analysis of research results

The cumulative mileage of the surveyed users is between 28-32 million kilometers, and the vehicle age is about 2 years. The user survey results are shown in Table 4.

Table 4 User survey data

Brand	A	B	C	D	E
number of failures per hundred vehicles	492	345	273	541	444
First failure mileage (10,000 kilometers)	10	12	14	15	14
Maintenance cost of 10,000 kilometers (yuan)	1577	1918	1890	1936	1717
quality satisfaction	7.63	8.2	8.05	7.65	8.27
after-sales satisfaction	7.05	8.1	7.6	6.97	7.76

In the user survey, the accumulative mileage of the users surveyed is between 280,000 and 320,000 kilometers, and the vehicle age is about 2 years. It can be seen from Table 3-2 that Vehicle D has the largest number of hundred-car failures and Vehicle C has the least. Vehicle D has the longest first fault mileage and Vehicle A has the shortest. Vehicle D has the most expensive maintenance cost of 10,000 kilometers, and Vehicle A is the cheapest. The quality satisfaction is consistent with the after-sales satisfaction results. The user evaluation of Vehicle B, C and E is better, and the user evaluation of Vehicle A and D is relatively poor.

From the survey, it is found that tractor users generally have low tolerance for failures. The average number of failures per 100 vehicles in the industry is 419, and there is still room for improvement in the quality of the tractor industry. In terms of power failures, the average number of 100-car failures is 138. Among them, miscellaneous failures, long faulty lights and battery failures occur more frequently, and fewer failures affect users ’normal driving. In terms of chassis failures, the average number of hundred vehicle failures is 56, of which, there are many miscellaneous failures, axle leakage / gear failures, and transmission failures. In terms of steering failures, the average number of 100-car failures is 67.7, with irregular tire wear being the most frequent. In terms of safety failures, the average number of failures per 100 vehicles is 31. Among them, there are many failures such as air leakage from the brake system, rearview mirror failure, and brake deviation. In terms of comfort failures, the average number of failures per 100 vehicles is 45, of which there are many problems with air conditioning and door sealing. In terms of drivability failures, the average number of failures per hundred vehicles is 39, mainly reflected in wipers and meters. In terms of electrical failures, the average number of 100-car failures is 55, mainly focusing on headlight failures. In terms of exterior and interior failures, the average number of 100-car failures is 14.7, with fewer failures overall. The first failure that affected operations occurred mainly around 13 kilometers. Regarding the maintenance cost of 10,000 kilometers, the user's small maintenance occurs at about 30,000 kilometers, and the large maintenance occurs at 80,000 to 90,000 kilometers. The tires are mostly replaced after driving for 140,000 kilometers, and the brake pads are replaced after driving for 200,000 kilometers. On average, users' maintenance and repair costs are less than 2,000 yuan per 10,000 kilometers, and tires are the main operating cost. In the user evaluation, overall, the user's quality evaluation is above 8 points, and the quality is considered good. Users are highly satisfied with power and safety. The users are less satisfied with the difficult faults that they are more concerned about. Solving the frequent occurrence of difficult faults is the main demand of the users. For internal and external decoration, comfort, etc., which have low impact on operations, user attention and quality evaluation are low, and improvements can be postponed. Users are less satisfied with the price. Users are less satisfied with the effect of dealing with problems, and more satisfied with the return visit to the service station.

4.3 Subjective evaluation

A number of experienced subjective evaluation engineers are used for evaluation. Taking the perceived quality of the first-level project as an example, the subjective evaluation scores of 5 semi-trailer tractors are shown in Table 5.

Table 5 Subjective evaluation score table

First-level project	Second-level project	Third-level project	A	B	C	D	E
Perceived quality	External perceived quality	Overall shape	8	8	7.5	7	7.8
		Assembly quality	8	7.75	7.25	7.25	7.8
		Sound quality of external opening and closing parts	8	7.75	7.0	7.25	7.5
	Internal perceived quality	Cabin layout	7.5	7.75	7.25	7.25	7.5
		Overall shape	8	8	7.5	7	8.25
		Assembly quality	7.75	7.5	7.5	7.25	8.25
		Internal sound quality	7.5	7.75	7.25	7.25	8.25
		Process, material	7.75	7.5	7.25	7.25	8.25
	Ease of maintenance	Checkability and convenience of liquid filling	7.25	7.75	7.25	7.5	7.5
		Disassembly and maintenance	7.25	7.75	7.5	7.25	7.5

According to the results of the subjective evaluation, the five vehicles are similar in terms of perceived quality, ergonomics, and driving performance, and the Vehicle E is slightly less comfortable. Since the five models are competing products, overall there is little difference in subjective evaluation.

5. Vehicle evaluation

5.1 Weight

During the evaluation of semi-trailer tractors, the overall performance (target layer) needs to be gradually decomposed into sub-index performance (criterion layer), and then further decomposed into test evaluation items (scheme layer) according to the different test evaluation methods or working conditions. Each sub-index of the criterion layer corresponds to a certain performance of the vehicle, and each test and evaluation item of the program layer is a more detailed specific evaluation of a certain part or aspect of a certain performance of the vehicle. In this multi-level and multi-index evaluation system, in order to determine the importance of each sub-index performance and test evaluation items in vehicle riding comfort, it needs to be weighted. The performance weighting coefficients are obtained from research and expert consultation methods. The weighting matrix for first-level indexes of driving safety, economy and efficiency, handling comfort, and subjective experience is $[0.33, 0.37, 0.20, 0.10]^T$. See the formula for calculating the evaluation score of the semi-trailer tractor:

$$CO = \sum_1^n CR * \eta \qquad (1)$$

Among them: CO is the score of a certain item, CR is the single score of the criterion layer, η is the weight coefficient of the criterion layer to the target layer, and n is the number of criterion layers.

5.2 Scoring Criteria

The performance of the semi-trailer tractor is evaluated by scoring and star rating. Taking emergency braking as an example, the scoring criteria are shown in Table 6.

Table 6 Criteria for emergency braking

Braking distance S for emergency braking(m)	Scoring interval	Evaluation mark
$65 \le S \le 68$	$92 \le V \le 100$	★★★★★
$68 < S \le 71$	$84 \le V < 92$	★★★★
$71 < S \le 74$	$76 \le V < 84$	★★★
$74 < S \le 77$	$68 \le V < 76$	★★
$77 < S \le 80$	$60 \le V < 68$	★

Note: The linear interpolation method is used to calculate the corresponding score in the interval segment. When the braking distance does not exceed 65m, it is calculated as 100 points. If the braking distance exceeds 80m, it shall be calculated as 60 points.

5.3 Evaluation Results

The third, second, and first-level evaluation indicators are weighted in turn to obtain semi-trailer driving safety, economy and efficiency, handling comfort, subjective experience, and total score results. See Table 7 for details.

Table 7 Evaluation results of semi-trailer tractor

Brand	Driving safety	Economy and efficiency	Handling comfort	Subjective experience	Total score	Evaluation mark
A	74.66	79.85	82.82	81.92	78.94	★★★
B	83.22	85.94	87.11	83.08	84.99	★★★★
C	80.97	88.47	87.88	84.82	85.51	★★★★
D	71.99	84.76	86.75	82.95	80.76	★★★
E	69.21	83.43	89.28	82.52	79.82	★★★

The evaluation results show that the total scores of the five vehicles are relatively concentrated. Vehicles B and C receive a four-star evaluation, and Vhicle A, D and E receive a three-star evaluation. Among them, the driving safety scores vary greatly, which has a greater impact on the total score. The selected 5 vehicles are the top 5 models in the semi-trailer market, with different performance priorities. The overall evaluation results are good, and there is still much room for improvement in terms of intelligent safety configuration and economy of use.

6. Conclusion

This paper builds a test evaluation system for semi-trailer tractors by analyzing the concerns and needs of users when buying cars and investigating relevant industry organizations. Based on the evaluation system, five hot-selling semi-trailer tractors were evaluated from the subjective and objective aspects, users, etc. The evaluation results showed that the system showed all aspects of vehicle performance and had certain guiding significance for vehicle development. Due to limited conditions, the structural strength of the cab and intelligent safety projects in the evaluation system have not been tested, and further research is needed.

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