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Original scientific paper

Research on Safety Investment Decision Evaluation and Optimization of Network Booking Taxi Platform Enterprise based on Subjective-Objective Assessment Method

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Abstract: This study addresses the current problem of disproportion between the investment and return of safety operation of Network Booking Taxi Platform Enterprises (NBTPE). This study selects the more representative NBTPE in the domestic travel field, and further forms a graph of safety input law based on the impact analysis of internal and external safety inputs by applying the System Dynamics method. Based on the comprehensive use of subjective empowerment method represented by analytical hierarchy process and objective empowerment method represented by entropy weight method, the study proposes the method of determining the reasonable proportion of each safety input cost through the comprehensive Subjective-Objective Assessment Method, and evaluates the feasibility and reasonableness of the method by using the method of linear regularization. Further the study concluded that enterprises need to increase the investment in equipment and facilities in the field of safety investment, while the proportion of investment in different links was measured and suggestions were made to optimize the current proportion of safety investment in NBTPE. This study provides support for optimizing the safety investment ratio of platform companies and improving the efficiency of safety management.

Keywords: Network Booking Taxi Platform Enterprises; transportation; optimization; safety input; safety production cost; subjective-objective assessment

1 INTRODUCTION

As a new mode of transportation and travel services that has emerged in China in recent years, network booking taxi provides passengers with greater travel convenience and personalized service supply. However, the studies by Cosenz [1] and Wang [2] further illustrate that companies are currently investing more in security, but are not clear about the direction of their focus. And because of the uncertainty of the direction of investment in safety operation resulting in safety investment, return is not a fully positive ratio. In spite of the enterprises in the safety operation of human and financial resources, some network booking taxi safety accidents still occurs. Although some scholars have used game theory to position the roles and responsibilities played by the government, enterprises and vehicle owners in the network booking taxi industry, there is a lack of targeted research on the definition of the direction of the enterprises' investment in safety and the determination of the proportion of investment. At the same time, because the network taxi platform itself has "Internet + transportation" industry complex characteristics, the actual level of safety operation is difficult to measure, the direction of safety investment is not enough to grasp, there is a total lack or structural irrational situation. Therefore, this study is dedicated to solving the problem of unclear direction of safety investment in the online taxi platform, while scientifically calculating the investment ratio of the safety operation area subsections of the online taxi platform to further improve the safety of the platform operation.

2 LITERATURE REVIEW

This section briefly presents the concepts related to platform enterprise security input expenditure.

2.1 Research Status

Many scholars have explored and researched this field of safety investment. For the research question, Dhanorkar [3] conducted a study on the impact of online taxi platforms on traffic and suggested that it may further lead to the generation of traffic congestion and affect traffic safety. Liang [4] proposed to establish a perfect market access and exit mechanism for online taxi to enhance government regulation of the industry from the source and improve market safety. Li [5] and Cao [6] proposed that only through collaborative governance can the online taxi industry achieve orderly regulation and ensure market safety. For the research methods, Jiang [7] established the evaluation model of safety input scheme based on entropy-approximated ideal solution ranking method to determine the best safety input ratio. Huang [8] was based on the Explanatory Structural Model method to analyze safety inputs in three dimensions: personnel, equipment, and management. Xu [9] introduced the cloud model theory based on the traditional hierarchical analysis method to determine the weight vector of each safety input evaluation index. Zhang [10] used the gray correlation analysis method to analyze and optimize the safety input structure. Han [11] established the safety input-output efficiency function based on the Constant Elasticity of Substitution (CES) production function. For the related research findings, Zhao [12] suggested that enterprise safety operations are influenced by several factors. Holtum [13] proposed that the group origin of drivers is an important influence on the safety of enterprise operations; Fu [14] proposed that the safe operation of online taxi enterprises is mainly determined by the efficiency of government regulation.

Combined with the current research status, the research questions of this study firstly target the specific direction and proportion of enterprise safety operation input, rather than going to the overall online taxi industry. Secondly, this study uses Subjective-Objective Assessment method including System Dynamic and Entropy Weight methods for the optimization weights of safety input categories and categories under the new business scenario of Internet enterprises and transportation services. Fewer studies have been conducted in this area. Thirdly, the conclusions of the study are further refined to the specific direction and proportion of enterprise safety investment, which enhances the practicality of the study.

2.2 Platform Enterprise Security Input Expenditure Direction

The input expenditure of platform enterprises is mainly divided into expenditure on internal management and expenditure on external operation of enterprises, among which internal management expenditure mainly involves internal management safety input and internal operation efficiency input; external operation expenditure mainly involves two inputs of online taxi operation service and safety, and further constructs a logic model (as shown in Fig. 1) to analyze the overall platform enterprise input situation, among which both internal and external inputs involve the input related to enterprise safety.

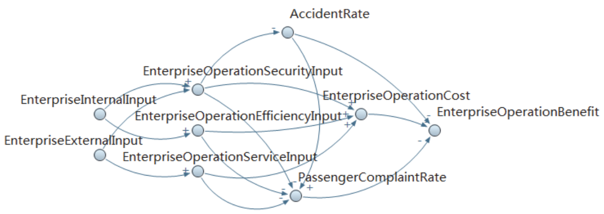

Figure 1 Logic model for input of NBTPE

Combined with Fig. 1, the increased investment in operational safety will lead to a decrease in the accident rate, which in turn will improve the efficiency of enterprise operations. The company's operational safety, operational efficiency, operational investment and accident rate all have an impact on service quality, which in turn affects passenger satisfaction and overall corporate effectiveness. Fig. 1 represents a logic model, the flow and impact of enterprise inputs to build a basic framework. On this basis, in order to further focus on the costs and benefits of enterprise safety inputs and better lay the foundation for the division and calculation of the influencing factors later, we combine Fig. 1 and the actual research on online taxi enterprises to further construct the dynamics model of NBTPE operation system as Fig. 2.

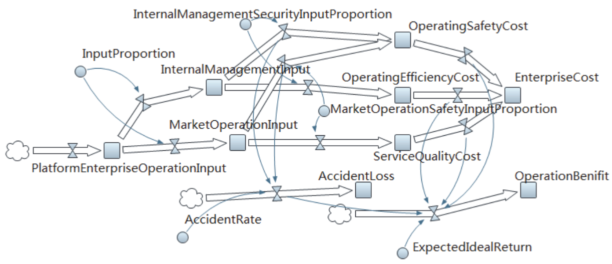

Figure 2 System Dynamics model of NBTPE

From the System Dynamics model, the proportion of internal and external safety input of enterprises determines the cost of enterprise operation safety, operation efficiency and service quality, while the proportion of safety management input, in addition to affecting the cost of enterprise operation, further affects the accident rate and accident cost of NBTPE, through the substitution of variables. Further calculation of the degree of influence shows that the impact of enterprise safety input on enterprise revenue is higher than the impact of operational efficiency and service quality input on enterprise revenue, but too high operating costs will also lead to the reduction of enterprise operating revenue [15]

To classify the categories of safety inputs, one is to use the literature review method. According to the Basic Specification for Enterprise Safety Production Standardization (GB/T 33000-2016), the Basic Specification for Transportation Enterprise Safety Production Standardization Construction Part 1: General Requirements (JT/T 1180.1-2018), and the Management Measures for the Extraction and Use of Enterprise Safety Production Costs and other relevant standard documents. Further clarifying the direction of safety investment should focus on management institutions and personnel, equipment and facilities, training and education, scientific and technological innovation and informatization, team building, hazard source identification and risk control, hidden danger investigation and management, occupational health, safety culture and other components of the operation and enhancement of the safety management system.

Second, the Delphi method is used, and each indicator is scored on a Likert 5-point scale to evaluate the convenience, simplicity, comprehensiveness, accuracy, and operability of the indicators, respectively, from "1" for "bad" to "5" for "very good". The indicators were selected by expert scoring.

On the basis of fully considering the operation mechanism and management characteristics of the NBTPE, following the principles of feasibility, science, system, coordination and dynamics, the three-level evaluation index system is established with the major categories of cost input, man-hour input and accident hazard. The cost input is divided into personnel input, hardware and software input and safety operation input; time input is divided into daily safety work time, as well as special circumstances to carry out safety special work time that requires the assistance of other departments; accident hazard is measured by the frequency of accidents and the impact of consequences [16]. The three-level index system framework of safety inputs shown in Fig. 3 was further established to facilitate the evaluation of enterprise inputs in a quantitative manner.

3 RESEARCH METHODOLOGY

In response to the problem of unclear safety investment direction and investment ratio of NBTPE it is needed to combine the subjective and objective laws based on the scientific use of analytical hierarchy process, Entropy Weight method, OLS. By using Subjective-Objective Assessment method it is claimed that the results are in line with the subjective and objective laws in order to provide an effective reference for enterprises.

To determine the optimal proportion of safety costs, since it is necessary to follow the objective law of safety input scale, and also to consider the enterprise's own operating characteristics, the proportion of safety input cannot be calculated simply by subjective methods or objective methods.

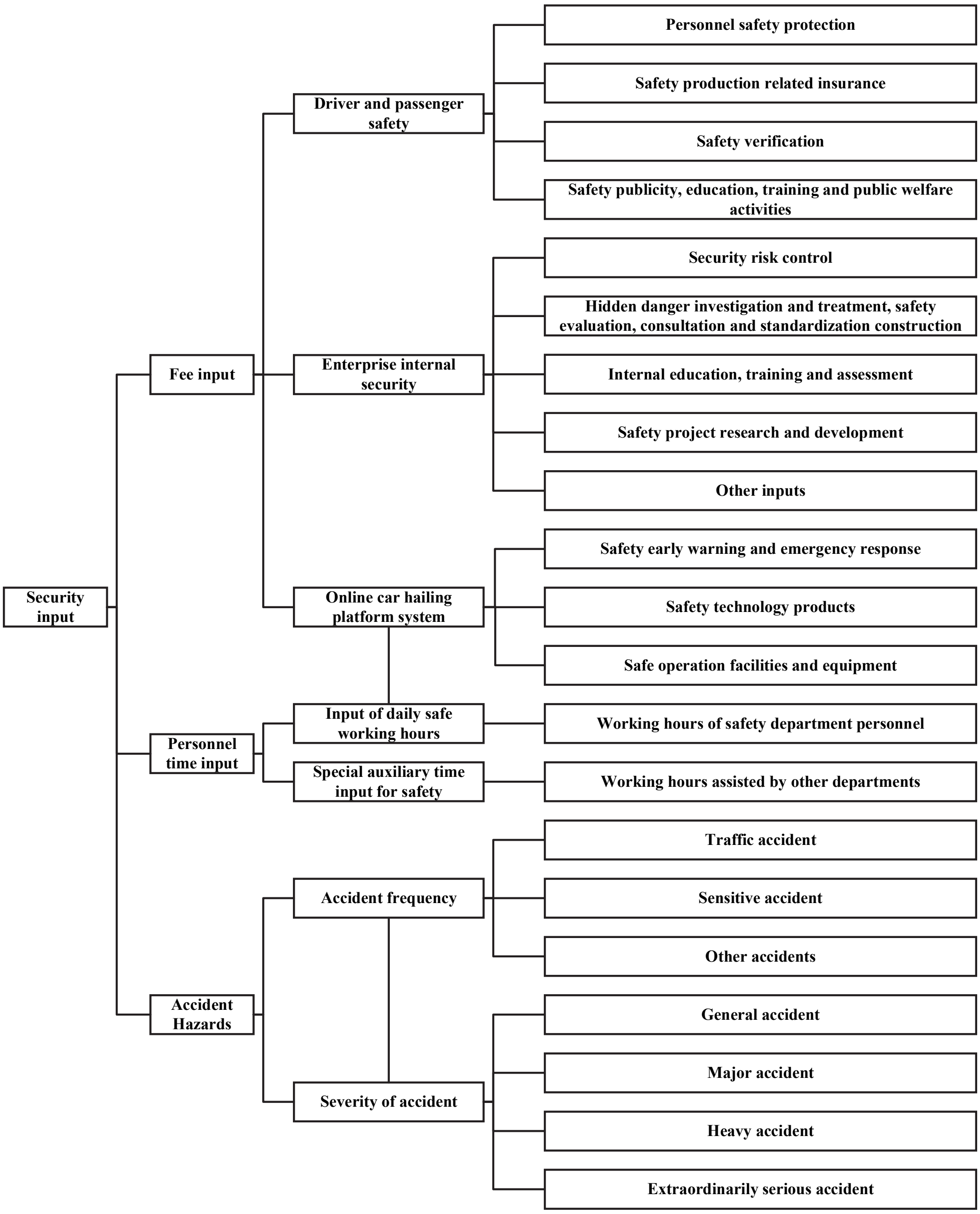

Figure 3 Frame diagram of safety input index system for NBTPE

Therefore, in order to take into account the preference of enterprise decision makers for the enterprise, while striving to reduce the subjective arbitrariness of the assignment so that the assignment of attributes achieves the unity of subjectivity and objectivity, and then makes the decision-making results true and reliable, the study adopts a combination of subjective-objective methods. Based on the inner law between index data and expert experience to assign weights to the decision indicators, the optimal proportion of safety costs is calculated using the comprehensive subjective-objective assignment method.

3.1 The Objective Law of Safety Input Scale

The benefit effect of safety input has indirectness, invisibility, uncertainty and hysteresis. From the graph of safety input law in Fig. 4, when the safety input is less than the safety destabilization point, the safety input has not been able to form the scale effect, and the growth of safety economic benefits is very slow. After exceeding the best safety input point, continue to increase the safety input, the safety benefit will instead decline, and it is blind input. For start-up and new economy enterprises with insufficient experience in safety input, the scale of input should not be smaller than the fixed figure of laws and regulations on the one hand, and on the other hand, when it is between the point of safety instability and the best input point, it is relatively economical and reasonable to gradually expand the scale of safety input for the benefit of enterprises [17].

Among all kinds of safety inputs, the most direct and effective quantitative control and adjustment of the enterprise is the cost input, and the detailed regulations on this input also reflect the main position of the cost input in the safety input. The next will mainly calculate and analyze the optimal ratio of safety cost investment, and promote the enterprise to the balance of safety benefits - economic benefits closer.

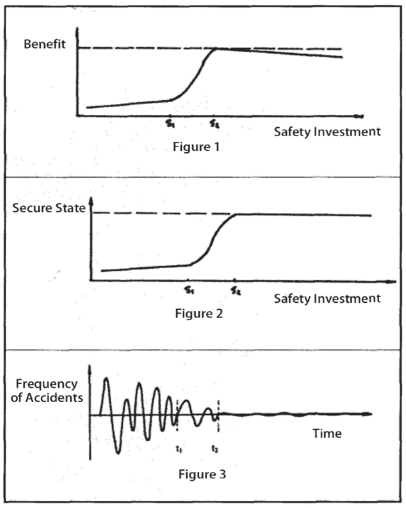

Figure 4 Safety input rule curve

3.2 Calculation of the Optimal Ratio of Safety Cost Input

According to the relationship between safety input and operation and accident reduction occurrence mentioned in 2.1, there exists an optimal ratio in the actual production process, so that the comprehensive evaluation of input and governance effect reaches the optimal value, and this optimal input point is the maximum benefit point pursued by enterprise safety management [18].

Based on the safety cost ledgers of three NBTPE in different development stages from 2018 to 2020, the project costs were classified and summarized according to the constructed index system, and the processed data were subjectively assigned with the hierarchical analysis method and objectively assigned with the entropy power method. Finally, the weights calculated by the two methods are judged comprehensively by the least squares method to obtain the best proportion of safety cost input.

3.2.1 Subjective Hierarchical Analysis Method Assignment

The AHP (Analytic Hierarchy Process) hierarchy analysis method constructs the judgment matrix in a hierarchical manner according to the interrelationship between the decision target, the consideration elements (decision criteria) and the decision object, normalizes the feature vectors to determine the weights, and finally uses the consistency index CI and the random consistency index RI to test the results.

The CI and CR are calculated by applying the hierarchical analysis method to the first-level indicators, the second-level indicators of cost category, the third-level indicators of hardware and software, and the third-level indicators of safety operation [19]. The CI and CR, compared with the consistency standard table, were <0.1, which met the consistency test requirements, and the test results are shown in Tab. 1.

Table 1 Analytic hierarchy process consistency test results

	Level 1 Indicators	Cost Class II Indicators	Transportation Service Safety Level 3 Indicators	Three-level indicators for daily operation of enterprises	Related Party Security Level 3 Indicators
Consistency Index CI	0.0018	0.0184	0.0091	0.0924	0.0477
Consistency ratio CR	0.0032	0.0318	0.0158	0.0915	0.0530

3.2.2 Objective Entropy Method of Empowerment

(1) Information entropy.

Mathematically, mean value is the probability of each possible outcome in a trial multiplied by the sum of its results.

The formula for information entropy is:

$$H(X) = -\sum_{i=1}^{q} p(x_i)\log(p(x_i)) \tag{1}$$

where H is the information entropy, q is the number of source messages, and $p(x_i)$ is the probability of message occurrence.

Information is a measure of the degree of order in the system, and entropy is a measure of the degree of disorder in the system; according to the definition of information entropy, information entropy is the expectation of the amount of information contained in an event for a certain indicator, the entropy value can be used to determine the discrete degree of a certain indicator, and the smaller its information entropy value, the greater the discrete degree of the indicator, the greater the influence (i.e., the weight) of the indicator on the comprehensive evaluation, and if the values of a certain indicator are all equal, then the indicator does not work in the comprehensive evaluation. Therefore, information entropy can be used as a tool to calculate the weights of each indicator to provide a basis for the comprehensive evaluation of multiple indicators.

1) Alkaline standardization of data of each index.

Suppose that k metrics $X_1, X_2, ..., X_k$ are given, where $X_i = \{X_1, X_2, ..., X_n\}$. Assume that the values of $Y_1, Y_2, ..., Y_k$ are normalized for each indicator data, then:

$$\begin{cases} Y_{ij} = \dfrac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} & (\text{Positive indicators}) \\ Y_{ij} = \dfrac{\min(X_i) - X_{ij}}{\max(X_i) - \min(X_i)} & (\text{Negative indicators}) \end{cases} \tag{2}$$

2) Find the ratio of each indicator under each item.

Let there be m secondary indicators of a certain level and n items of data have been obtained, which is noted as matrix. Under the same indicator, the formula to calculate the weight of each taken value to the whole is as follows:

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} (i = 1, 2, ..., n; j = 1, 2, ..., m) \tag{3}$$

3) Find the information entropy of each indicator.

$$E_j = -\ln(n)^{-1} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{4}$$

Which $p_{ij} = y_{ij} \Big/ \sum_{i=1}^{n} Y_{ij}$ ($p_{ij} = 0$, then define $E_j = 0$)

4) Determine the weights of each index.

According to the formula of information entropy, the information entropy of each information index is calculated as E_1, E_2, ..., E_k. The weights of each index are calculated by information entropy $W_i = \dfrac{1-E_i}{k-\sum E_i}$ $(i = 1, 2, ..., k)$

3.2.3 Least Squares Integrated Weighting Method

The hierarchical analysis method is a method that favors the subjective opinion of experts and considers some decision-making factors in practice, while the entropy weighting method is a method to determine the weights based on the information entropy of the actual observations of the data. In order to more accurately and comprehensively determine the industry's best input ratio of safety costs, a deviation function is introduced and the weights of the two methods are judged comprehensively using the least squares method.

Construct the Lagrangian function $y = f(x, \omega)$, where y is the objective function. x is the weight ratio , $\omega=[\omega_1, \omega_2, ..., \omega_n]^T$ is the weight to be determined in order to find the optimal estimate of the parameter ω of the function $f(x, \omega)$, The objective function $L\left(y, f\left(x, \omega\right)\right) = \sum_{i=1}^{m}\left[y_i - f\left(x_i, \omega_i\right)\right]^2$ is solved for the given four sets of observations. The value of ω corresponding to the minimum value is the desired one.

The combined weights determined by the least squares method are calculated as shown in Tab. 2.

Table 2 Result of the least square method

Secondary Indicators	WeightingW2c	Tertiary indicators	WeightingW3c
Transportation Service Safety	0.34	Security Facilities and Equipment	0.37
		Security Warning and Emergency Response	0.32
		Security Technology Products	0.31
Daily operation of the enterprise	0.38	Other Inputs	0.22
		Internal education, training and assessment	0.33
		Safety inspection, consultation, standardization	0.14
		Safety risk control	0.19
		Safety project R&D	0.12
Related Party Safety	0.28	Safety production related insurance	0.18
		Safety verification	0.28
		Safety promotion, education, training and public welfare	0.33
		Personnel safety protection	0.21

The least-squares combination of empowerment takes into account the objective and subjective empowerment, and the safety cost investment of NBTPE at different stages of development, which is a more suitable allocation ratio for safety investment, and each company can take this ratio as a guide and adjust it in the direction of the optimal ratio in accordance with its own development.

4 EVALUATION OF THE EFFECTIVENESS OF SAFETY INVESTMENT

Increasing safety investment towards the optimal investment point and reasonably allocating resources are effective in reducing accidents and stabilizing overall profitability of an enterprise [20]. Here, we take enterprise D as an example to analyze the effectiveness of rational planning of safety investment based on optimization algorithm.

4.1 Verify the Reasonableness of the Actual Safety Investment of the Enterprise

Due to the differences in the nature and operation of each enterprise, a more accurate way to evaluate the reasonableness of the safety input of a specific enterprise is to use the historical safety input-accident data to make prediction judgments, so the method of linear programming is introduced. Linear programming (LP) is a mathematical theory and method to study the extreme value of linear objective function under linear constraints, listing the objective function and constraints, and finding the optimal solution of the objective function in the feasible domain. By establishing the input ratio of each project and the constraints between the treatment effects, the input ratio of each project is found when the treatment effect meets the requirements and the minimum amount of input. The monthly safety input and safety index data of enterprise D were correlated and analyzed to derive the unit input-output benefit matrix ***R***. The constraints included safety system compliance, satisfaction of regulators, traffic reduction, driver-rider conflict reduction, physical and mental health protection, labor rights protection, driver. The constraints include safety system compliance, regulatory satisfaction, traffic reduction, driver-rider conflict reduction, physical and mental health protection, labor rights protection, driver experience, passenger recognition, other benefits, etc. The objective function and constraints are constructed as follows:

$$\min Z = \sum_{i=1}^{10} f_i \cdot x_i \tag{5}$$

$$s.t. \quad R_{kj} x_j \geq S_k \quad (k \in [1, 9] \;, x > 0, \; j \in [1, 10]) \tag{6}$$

According to the 10 independent variables and 9 constraints, the optimal assignment value is obtained, and the comparison with the current actual safety investment ratio of the enterprise is shown in Tab. 3 (the driver and passenger education and internal education are combined into the publicity and education training costs, the safety project research and development is included in the safety technology costs, and the other costs are not included for the time being because the range of uses is diverse and the effect is not easy to measure). It can be seen that the current actual safety investment ratio of the enterprise is mostly around the optimal solution, and the next development direction can be appropriately tilted towards safety verification and safety technology.

Table 3 The comparison between the optimal investment ratio and the actual investment ratio

	LP Optimal Empowerment	Enterprise actual
Facilities and equipment for safe operation	18.63%	20% ~ 30%
Security verification	5.26%	1.5% ~ 3%
Safety warning and emergency response	13.92%	8% ~ 15%
Safety risk control	10.16%	10% ~ 15%
Hidden danger investigation and management, safety evaluation, consultation and standardization	11.23%	5% ~ 10%
Publicity, education and training	13.16%	20% ~ 25%
Safety-related insurance	5.84%	6% ~ 12%
Safety technology	8.46%	1% ~ 2%
Personnel safety protection	13.33%	5% ~ 12%

4.2 Verify the Significance of the Enterprise's Effect of Reducing the Occurrence

Take the more well-developed enterprise D as an example, according to the actual safety input ratio of the enterprise shown in Tab. 3 after one year of implementation. The effect of reducing the occurrence is shown in Tab. 4.

Table 4 Security Service completion in 2021

Category	Indicator item	Compared to 2020
Sensitive Events	Major Liable Accidents	−23%
	Passenger complaint driver 10,000 orders occurrence rate	−17%
Traffic Events	Multiple casualty case rate	−7%
	Billion kilometers dead serious injury rate	−15%
Stabilization and Epidemic Prevention Events	Number of actual mass incidents	−67%

It can be seen that Enterprise D has achieved a good effect in reducing the occurrence of sensitive conflicts, traffic accidents and stability maintenance incidents, which is inseparably related to its special management activities. In response to sensitive incidents, the company opened a special safety warning education to avoid violent conflicts and sexual harassment in the monthly driver education, and increased the investment in publicity and education, so the number of sensitive incidents decreased. Faced with the social situation that the new crown epidemic continues to spread, the company has strengthened the safety protection of personnel in terms of epidemic prevention. For high-risk areas, online taxi drivers are required to disinfect their vehicles after each order and install transparent protective film inside the vehicle. Through daily offline activities and online communication, the driver service manager is guided to continuously pay attention to the driver's physical and mental health, mood swings and family situation. However, in contrast, the effect of the epidemic affected by the reduction of traffic incidents is not yet ideal, in the adjustment of the governance program, in addition to the existing road traffic safety education knowledge to repeatedly promote, weekly transmission, so that common sense safety internalized into the driver's safety awareness, while enterprises should also increase the use of high-tech new technological means to continue to expand the safety management boundary.

The actual investment in safety verification and safety technology is 1.5% ~ 3% and 1% ~ 2% respectively, which is still a certain gap compared with the optimal input point of 5.26% and 8.46% calculated by the optimal model, and the industry optimal input ratio of 7.54% and 9.03% calculated by the composite model in this paper. And in the facilities and equipment of safe operation and safety-related insurance links appear the actual investment 20% ~ 30% and 6% ~ 12%, which is significantly higher than the optimal ratio of 18.63% and 5.84%. It has led to an unreasonable investment in safety in the segment, which has resulted in insignificant year-over-year decreases in safety operations such as traffic incidents. For this part of the input, enterprises can consider further transfer to the safety verification and safety technology, in the case the total amount of safety investment remains unchanged to optimize the proportion of investment to achieve better results. For the other segments, the actual inputs of the companies basically remain near the optimal results. Therefore, according to the optimal input ratio of enterprises for safety investment, it can effectively reduce the incidence of accidents, reduce personal injury and death, and enhance the return of enterprises to enhance safety investment under the same total input.

5 CONCLUSIONS

By applying the Subjective-Objective assignment method, this study initially determines the safety input index framework and uses the subjective-objective assignment method assessment method to analyze the safety input of NBTPE. And combined with the example data, we use linear programming and other methods to evaluate the actual input situation of NBTPE and draw the results. Four conclusions can be obtained from this study, which provide a path reference for the industry management to carry out safety operation level measurement and companies' platform self-assessment, as follows:

(1) When enterprises invest in safety, they should invest more human and material resources in facilities and equipment for safe operation, specifically in the updating, maintenance, timely repair of equipment and application of information data. In the actual application, the NBTPE often invest too much in this area, accounting for almost 30% of the overall safety investment, so the enterprises that invest too much can appropriately adjust the proportion of

investment downward, less than 20% of the investment is a relatively reasonable proportion.

(2) Relevant safety warning and emergency response, personnel safety protection, and investment in education and training should be almost equally important, including the development of supporting policies and systems, the clarification of the corresponding processes, the division of personnel responsibilities, and the development of regular training and education courses. In practice, enterprises in the safety of early warning and emergency response link input are more reasonable; in the personnel safety protection link input is less, in the publicity and education training input is higher and should further adjust the input ratio in personnel insurance purchase, personnel safety system development and other aspects of increased investment. All three input ratios in the overall investment of 12% - 14% is appropriate.

(3) Hidden danger investigation and management, safety evaluation, consultation and standardization, as well as safety risk control inputs compared to the previous link, the proportion of inputs should be appropriately reduced, specifically for the assessment of the relevant situation, the remediation of the problem, the development of standards and norms, etc. . In the actual investment, enterprises tend to pay less attention to the hidden danger investigation and assessment, the proportion of investment is often less than 10%, while the investment in safety risk control is slightly higher. The two should be further balanced in the investment, each accounting for 10% - 12% of the investment is appropriate.

(4) Safety technology, safety-related insurance, security verification compared to the aforementioned, should be kept at a relatively low input ratio, which specifically includes the research and development of new security products, the purchase of enterprise security insurance products, real name information filling and certification, etc. In the actual investment, the proportion of enterprise investment in safety technology research and development and safety verification is too low, while the purchase of insurance is a too large investment and should be further balanced so that the investment in safety technology should be about 8% - 10%, the remaining two should be about 5% - 6%.

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