Research Article

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Heuristic decision of planned shop visit products based on similar reasoning method: From the perspective of organizational quality-specific immune

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Abstract: The purpose of this study is to reduce the maintenance time, cost, and scheduling distance and to determine the maintenance priority of planned shop visit products. This study introduces the concept of maintenance map, establishes the evaluation indicators system of maintenance map from the perspective of organizational quality-specific immune, and puts forward two key dimensions named maintenance plan and technical support of maintenance map. Based on the theoretical framework, construct a heuristic decision model of planned shop visit products based on similar reasoning, set the maintenance services data of Harbin Dongan Engine Co., Ltd., as research objects, and use the concrete schemes and cases to solve and carry out an empirical analysis of the heuristic decision of planned shop visit products based on similar reasoning with the help of the ant colony algorithm; the empirical analysis results indicate that maintenance map and evaluation indicators system are the fundamental basis of the heuristic decision based on similar reasoning, the combinations of similar reasoning and ant colony algorithm can achieve the optimal heuristic decision of planned shop visit products, which have effectiveness, feasibility, and operability. This research will be conducive to give out the heuristic decision of scheduling schemes of planned shop visit products, which will be beneficial to enhance maintenance efficiency and quality, promote learning effects and learning pattern paths, and reduce maintenance scheduling distances of planned shop visit products from the aspects of theoretical framework guidance, empirical system enlightenment, and conceptual paradigm reference.

Keywords: planned shop visit products, similarity principle, similar reasoning, heuristic decision

1 Introduction

When the automobile engine is not suitable to drive or has driven to a certain mileage, it must be repaired according to the airworthiness requirements. At present, automobile companies regularly provide users with engine repair services. According to the engine damage, the usage limit time, and other factors, companies develop the planned shop visit schemes of different levels. The noneconomic and economic analyses of unpredictable products are carried to determine the feasible repair or maintenance to a greater degree. Because the engine repair level and maintenance costs are closely related, when the maintenance grade is unreasonably set too high, the corresponding maintenance time and material costs will substantially increase, leading to a huge waste for the users and enterprises. At present, the domestic 4S shops and the users lack reasonable controlling methods of maintenance level, making the engine repair costs account for more than 60% in the maintenance costs.

The viewpoint of quality is the life of an enterprise is advocated by every enterprise in various sectors and industries [1–13]; the quality and quantity of maintenance and repair products (planned shop visit products) are the attribute reflections and evaluation indicators of quality; furthermore, plan, technology, and technical innovation are the key factors of quality for planned shop visit products of every enterprise in various sectors and industries. Therefore, ensuring the maintenance quality, enhancing maintenance efficiency, improving maintenance outcome, reducing maintenance cost, decreasing maintenance time, and scheduling distances of planned shop visit products with the help of organizational quality-specific immune, maintenance map, and two dimensions named maintenance plan and technical support of maintenance map are all important for sustainable quality development and quality

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maturity of every enterprise in various sectors and industries.

In addition, due to a large number of auto users, enterprises will receive a large number of planned shop visit requests in a period of time. Their maintenance personnel, equipment, and technical capacity are limited, and the incorrect scheduling program will increase the maintenance costs, which leads to users' withdrawal expenses and complaints against the repair service, finally affects corporate reputation. These parts of the hidden costs have a significant impact on the repair costs which cannot be ignored. Therefore, how to determine the maintenance grade and scheduling program is an important issue for making a repair decision. This study establishes maintenance map and model, chooses and extracts scale and evaluation indexes from the perspective of the organizational quality-specific immune [14–18] (the core element and construction dimension of organizational quality-specific immune is organizational quality defense), and further establishes heuristic decision model based on maintenance map and similarity reasoning, finally carries out an empirical analysis of the established evaluation indexes, map, and model. The theoretical framework and empirical analysis provide theoretical reference and practical guidelines for the maintenance map, heuristic maintenance schedule, and heuristic decision of planned shop visit products.

2 Definition and connotation of the concept

Service for the planned shop visit engines is a kind of after-sales service. When the engines bought by the purchaser do not work or when it reaches a certain time limit for usage, needed to be maintained, the buyer needs to send the engine to the maintenance site for after-sales maintenance services. Repair decision-making refers to such a process: based on the information of each engine, the enterprises determine the grade of a planned shop visit and develop a reasonable decision-making program according to their own maintenance resources to minimize the maintenance costs for enterprises and users.

Research based on similar reasoning originated from the exploration of human reasoning and learning mechanisms from the perspective of cognitive science. Man is an intelligent system, completing work by means of similar memories usually; naturally, this empirical reasoning method can be used for artificial intelligence

research and application. The reasoning based on similarity plays a role in optimizing the planned shop visit decision in the following aspects: (1) Acquire maintenance knowledge: develop maintenance knowledge rules to reduce the time for maintenance personnel to find maintenance knowledge through the close cooperation between experts and knowledge engineers of this field. (2) Keep maintenance knowledge: with the changes in the maintenance task, the maintenance knowledge of maintenance personnel needs to be adjusted, the new knowledge may conflict with the original knowledge, so the maintenance teams produce a large number of structural losses. And similar reasoning can preferably solve such problems. (3) Improve the efficiency of solving the problem: similar reasoning can accelerate the maintenance speed through the reuse of existing maintenance programs and the use of successful experience and can avoid the wrong maintenance program through the failure of existing maintenance experience.

GJB2916-97 identifies analysis principles and methods of basic maintenance grade, including an economic assessment, noneconomic assessment, sensitivity assessment, and development of maintenance grade analysis reports. Zhang et al. (2005) [19] studied the relationships among the engine state parameter and the performance of each unit body by using the variable precision rough set theory from data mining and proposed a method of maintenance grade decision-making of aeroengine of attribute reduction based on information entropy. Xia (2009) [20] applied a fuzzy decision-making method to prioritize the equipment to be repaired. Yong (2008) [21] established the rule base of maintenance level reasoning of the unit, realized the decision of engine work scope based on WPG, and proposed the decision method of the engine working scope based on case reasoning. Many scholars studied the issue of multiple engine repair, regarding the maintenance level of several engine units and component replacement strategy as a multiobjective optimization problem. As a goal for minimizing the repair time and cost and maximizing the service time, a two-step model is established. The first step is to convert the multiobjective optimization problem into the single-objective optimization problem, and the second step is to use the genetic algorithm to solve [22].

Jin and Jiang (2011) [23] established a multiobjective joint optimization model for a preventive maintenance plan and production scheduling of single equipment. Take the maintenance cost, the maximum completion time of the production task, the weighted total completion time, and the weighted total delay time as a target, the multiobjective genetic algorithm was used and the preventive maintenance plans and production schedules

were optimized. Fu and Zhong (2010) [24] took the spare aeroengine soft constraint fitness as an objective function to establish a multiobjective combined optimization model for aeroengine maintenance plan and proposed a heuristic algorithm based on progressive structure strategy to solve the problem, providing the theoretical basis for the construction and the selection method of aeroengine maintenance plan set. Kennet (1994) [25] designed a model based on the stochastic dynamics of invalidity risk costs and overhaul costs to determine the optimal repair time for aeroengine. Bai et al. (2007) [26] used a modern sorting theory to aim at the minimization of the lack of time and proposed to improve the priority algorithm of online maximum processing time for repair scheduling. Taking the actual situation into account, the aeroengine repair needs to meet a number of conflicting constraints [26]. Stranjak et al. (2008) [27] used the simulation model to carry out maintenance schedules with the negotiation strategy. The existing literature made a useful discussion on the engine repair grade assessment and repair scheduling problems, but the problem of car engine repair is not so complicated as the problem of aircraft engine repair, and due to its particularity, it is necessary to do the adaptive improvement and innovation based on existing research.

3 Model construction

3.1 Modeling problem description and basic assumptions

3.1.1 Modeling problem description

The engine maintenance decision contains the following principles: (1) determine the maintenance plan. First, define the maintenance requirements of the engine, determine the maintenance grade and maintenance range, and ensure the engine's safety and reliability after the repair. Second, understand the customer's time requirements to ensure the completion of the maintenance mission and other technical objectives. (2) Determine the technical support required to complete the maintenance plan, including the support equipment, the type of workforce, the technical level, the maintenance facility and their usable hours which are required to complete the maintenance tasks. (3) During the period of determining the implementation of maintenance level and maintenance range, try to consider the mature maintenance ideas, and use the same method to

solve the same problem to reduce the maintenance time [28]. (4) Try to make the equipment close to the user of the equipment and, as far as possible, change the parts to ensure better mobility, to maximize the use of security equipment of all levels and the existing technical conditions to complete similar maintenance tasks to reduce maintenance costs. (5) Requirements of maintenance workforce and materials for maintenance implementation should adapt to the corresponding maintenance capacity, and structural losses caused by changes of work types for repairing different engines should be avoided as far as possible [29]. According to the above principles, this paper argues that the problems on repair decision-making on the planned shop visit product can be transformed into three parts: (1) Set its unique attribute space for each planned shop visit product, so that it is unique in this space. How to mark the planned shop visit product on the maintenance map is a basic prerequisite for making repair decisions. (2) Determine the similarity of the planned shop visit product is an important issue to avoid frequent changes in maintenance plans and maintenance capacity in the maintenance process. (3) In a large number of planned shop visit products, how to develop the largest learning curve and an optimal maintenance scheduling of smallest changes in personnel and equipment.

Therefore, first, this study establishes the maintenance map of the planned shop visit product and positions it from the maintenance plan and the technical support required for each planned shop visit product. Second, a similar reasoning theory is used to calculate the priority of the planned shop visit product. And then use the heuristic algorithm to find a set of the shortest and most economical repair scheduling program within the target range to help the enterprise complete all repair requests.

3.1.2 Basic model hypotheses

This study mainly focuses on the combination of similar reasoning and heuristic algorithm. Therefore, according to the research results of relevant literature and references [20], it is necessary to establish the following hypotheses on the maintenance grade of planned shop visit products and the optimization of the maintenance decision by using the heuristic algorithm without affecting the results.

Hypothesis 1. Each repair product's size has no difference on the maintenance map. The time the ants crawl over the product is negligible, and each ant could secrete an equal amount of pheromone [20].

Hypothesis 2. After a limited movement, each artificial ant has built a solution to the problem.

Hypothesis 3. The internal states of the subsequent ants store all information about the past.

Hypothesis 4. The ant decision table is a probabilistic function that is determined by the pheromone function and the heuristic information function. The ant uses this probability function to guide its search to select the most probable planned shop visit product in the maintenance map.

3.2 Heuristic decision model based on similarity reasoning

3.2.1 Maintenance map

Scholars have deeply researched into the relevant contents of fusing biological immune into management scope and field, and further they have obtained many achievements and literatures and have formed the overall theoretical framework and practical system of organizational immune, the elements, core components, and construction dimensions of organizational immune, which are organizational monitoring, organizational defense, and organizational memory, respectively [30–32]. Scholars have carried out the achievements and literatures of fusing biological immune into quality management scope and field with the help of organizational immune [14–17,33,34]. Quality is the life of enterprise, so guaranteeing and refining organizational quality is the key goal of the enterprise and organizational development. Refer to the outstanding achievements of organizational immune, organizational quality immune is the core architecture of organizational immune, namely which is the reflection and characterization of organizational immune at the quality level [14–17,33,34]. Organizational quality immune refers to the capability that organizations distinguish internal and external alien elements and the threat that affects organizational quality, excludes and removes the factors that are threat to organizational quality, and generates the memory interrelated to organizational quality to enhance organizational quality performance and safeguard organizational health [14–17,33,34]. Organizational quality immune is consisting of organizational quality-specific immune and organizational quality nonspecific immune. Organizational quality-specific immune is the kernel and key construction dimension of organizational

quality immune, which refers to that with the help and function of pre-set organizational quality nonspecific immune (specifically refer to organizational quality resources, organizational quality culture, and organizational quality institution and rules), organizations adopt the acquired, noncongenital, specific quality immune respond behavior to internal and external sudden quality safety incidents and threat factors through three lines of defense of organizational quality monitoring, organizational quality defense, and organizational quality memory [14–17,33,34]. Learning from the construction components and construction dimensions of organizational immune, organizational quality-specific immune mainly consisted of organizational quality monitoring, organizational quality defense, and organizational quality memory. The organizational quality defense is the core element and key construction dimension of organizational quality-specific immune. Organizational quality defense refers to a series of behavior that organizations resist and eliminate internal and external sudden quality safety incidents and threat factors with the preconditions of organizational quality monitoring, which is reflection and characterization of organizational defense at the quality level [14–17,33,34].

Referring to the perspective of organizational quality-specific immune, organizational quality defense is the core element and construction dimension of organizational quality-specific immune; this study chooses the scale and evaluation indexes with the help of organizational quality defense (organizational quality defense soft elements and organization quality defense hard elements) and organizational quality management practice. As for contents, outlines, characteristics, and purposes of products maintenance and maintenance map, organizational quality defense is the core part and component of organizational quality-specific immune and organizational quality management practices; organizational quality defense is aimed at maintenance plan dimension and technical support dimension [35–46]. The scale and evaluation indexes are given in Table 1 from the perspective of organizational quality defense [35–46].

To construct the visualized two-dimensional maintenance map model, this study reduces the dimension of many attributes of the planned shop visit product by the optimal scale method according to the similarity characteristics of the classification standard of the planned shop visit product and its grade. And finally, it will be expressed abstractly with the two dimensions of the maintenance plan and technical support [47–49].

The choice of indicators is a key factor for the maintenance map to correctly reflect the interrelationships between the planned shop visit products and other

Table 1: Summary table of maintenance map variables

Target layer	Factor layer	Variable layer	State layer
Maintenance map index system	Maintenance plan dimension	Maintenance requirements A_1	Maintenance grade A_{11}
		Maintenance complexity A_2	Maintenance range A_{12}
		Maintenance personnel B_1	Customer time requirements A_{21}
	Technical support dimension	Maintenance equipment B_2	Total hours of repair A_{22}
			Work structure B_{11}
		Maintenance capacity B_3	Working hours available B_{12}
			Number of devices available B_{21}
			Number of hours available for equipment B_{22}
			Maintenance probability B_{31}
			Maintenance strength B_{32}

planned shop visit products [50]. This study attempts to set up the index system from the maintenance plan and technical support [21]. In the dimension of the maintenance plan, this study chooses two aspects of maintenance requirements and maintenance complexity as the concrete indexes. In the technical support dimension, this study chooses three aspects: maintenance personnel, maintenance equipment, and maintenance ability. The model variables are summarized in Table 1.

3.2.2 Evaluation of product grade based on similar reasoning

In each dimension, $\{x_1, x_2, \dots, x_m\}$ indicates the input vector of dimension m , which represents the attributes of m planned shop visit products. As shown in Figure 1 (grade evaluation of the planned shop visit product based on similar reasoning), the input vector needs to be normalized, and the value is transformed between 0 and 1, y is taken as the output, representing the maintenance grade.

Figure 1: Grade evaluation of the planned shop visit product based on similar reasoning.

The number of hidden nodes in the single-output sub-neural network model is q , the activation function of the hidden layer node is $f_H(x)$, the threshold is θ_j ($j = 1, 2, \dots, q$), the number of output nodes is 1, the activation function of the hidden layer node is f_o , and the threshold is β . The connection right of hidden node i and input node j is ω_{ij} , then the connection right of hidden node i and the output node is ω_i . Then,

$$y = \sum_{i=1}^q \left\{ \omega_i f_o \left[\sum_{j=1}^m \omega_{ij} f_H(x_{ij}) + \theta_j \right] \right\} + \beta_i \quad (1)$$

In equation (1), the activation function is a Gaussian function:

$$f_o(x) = f_H(x) = \text{Similarity}(T, X) = e^{-\frac{(x-x_i)^2}{\sigma^2}}$$

X is a planned shop visit product; T is the priority of the planned shop visit product; n represents the number of attributes of the planned shop visit product; f is the similarity function of attribute i in the planned shop visit product X and the standard grade T ; and ω represents the weight of attribute i and the sum of all attributes' weights is 1.

It can be seen from formula (1) that y is a probability matrix $1 \times q$, and if y is the maximum value in y , it is judged that the planned shop visit product is the product of grade i .

This study uses an error feedback design of a genetic algorithm to make network training for the main parameters:

$$E = \frac{1}{2} \sum_{i=1}^r (t_i - y_i)^2 \quad (2)$$

t_i is the expected output value, y_i is the actual output value, and r is the number of samples. To make E reach

the minimum, this study uses the ladder algorithm, the adjustment formula of the specific parameters is as follows:

$$\begin{cases} w_{ij}(k+1) = w_{ij}(k) - \beta \frac{\partial E}{\partial w_{ij}} \\ \bar{x}_{ij}(k+1) = \bar{x}_{ij}(k) - \beta \frac{\partial E}{\partial \bar{x}_{ij}} \\ \sigma_{ij}(k+1) = \sigma_{ij}(k) - \beta \frac{\partial E}{\partial \sigma_{ij}} \end{cases} \quad (3)$$

3.2.2 Heuristic maintenance scheduling

Referring to the research results of literatures and references [47–52], this study constructs the relevant model of heuristic maintenance scheduling. Heuristic maintenance scheduling utilizes the Ergodic principle; the planned shop visit product can be seen as every city in TSP problem, whereby the original model is modified as follows: Let m be the number of ants in the ant colony, $d_{ij}(i, j, \dots, n)$ represents the distance between the planned shop visit product i and the planned shop visit products j , $\tau_{ij}(t)$ stands for the connection pheromone between the planned shop visit product i and the planned shop visit products j at time t . At the initial moment, all schemes pheromone concentrations are constant. Set $\tau_{ij}(0) = C$ (C is a constant). In the course of the movement, ants $k(k = 1, 2, \dots, n)$ transfer the direction according to the pheromone concentration of each path. $P_{ij}^k(t)$ is the probability of the ant k moving from the planned shop visit product i to the planned shop visit products j at time t , $\text{tabu}_k(k = 1, 2, \dots, n)$ is the set of planned shop visit products repaired by the ant k . η_{ij} is the heuristic factor, and it is a visibility of the path here, i.e., $1/d_{ij}$, d_{ij} is the Euclidean distance of knowledge i to j , α is the information heuristic factor, indicating the relative importance of the trajectory, β is the expected heuristic factor, indicating the relative importance of the visibility, s is the product in the set of the planned shop visit product allowed to be chosen by ants k in the next step, allowed d_k is the planned shop visit product allowed to be chosen by ants k in the next step. Formula $P_{ij}^k(t)$ is

$$P_{ij}^k(t) = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha \cdot [\eta_{ik}(t)]^\beta}{\sum_{s \in \text{allowed } d_k} [\tau_{is}(t)]^\alpha \cdot [\eta_{is}(t)]^\beta} & \text{if } j \in \text{allowed } d_k \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

After making one decision, the concentration of the pheromone on the path needed to be updated according to the following formula:

$$\begin{cases} \tau_{ij}(t+n) = (1-\rho) \cdot \tau_{ij}(t) + \Delta \tau_{ij}(t) \\ \Delta \tau_{ij}(t) = \sum_{k=1}^m \tau_{ij}^k(t) \end{cases} \quad (5)$$

In formula (4), ρ represents the pheromone volatility coefficient, $1-\rho$ represents the pheromone residual factor, $\rho \in [0, 1)$; $\Delta \tau_{ij}(t)$ represents the pheromone increment on the path in this cycle and the initial time; $\Delta \tau_{ij}(0) = 0$; $\Delta \tau_{ij}^k(t)$ means that the amount of information left on the path in this cycle by ant k .

In the ant-cycle model:

$$\Delta \tau_{ij}^k(t) = \begin{cases} \frac{Q}{L_k} & \text{if the } k\text{-th ant goes through} \\ & (i, j) \text{ in this cycle} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

In formula (6), Q represents the pheromone intensity and L_k represents the total length of ant k walking in this cycle. Through the phenomenon that the ant group traverses the knowledge cluster many times, the pheromone concentration of the ants left on the best path is stronger than that of other paths and is maintained at a certain level. Therefore, this path can be regarded as the best maintenance decision to be found.

4 Empirical analysis

4.1 Data source and schemes

This study refers to the related data of planned shop visit engine service in Harbin Dongan Engine Co., Ltd., in the third quarter of one certain nearby year. During this quarter, engines were required to carry out maintenance services.

4.2 Empirical analysis processing and results analysis of schemes

The key and main empirical analysis processing are as follows:

Step 1, data standardization. Take the optimal scale method to reduce attributes of planned shop visit products to two dimensions.

Step 2, maintenance map drawing. According to the coordinates obtained from the calculation in the above, a maintenance map is established and each planned shop visit product is shown, as in Figure 2. The

Figure 2: Maintenance map of the planned shop visit product.

maintenance decision on the planned shop visit product is made in accordance with the traditional evaluation of the grade classification and capacity scheduling program, as shown in Figure 3. Figure 2 shows the use of the maintenance services data of planned shop visit products of Harbin Dongan Engine Co., Ltd., to set up maintenance map, analyze the product position in the maintenance map, and expound the maintenance scheduling distances in maintenance map according to two dimensions and related standards. The classification of the maintenance products into categories, grades, and clusters according to the traditional evaluation method and grade level method with the help of related dimensions and empirical analysis data is shown in Figure 3.

Figure 3: Traditional grading method.

Table 2: Grade determination of planned shop visit products

Maintenance grade coordinate	Classification standard of the planned shop visit products		
	Delay maintenance	Priority maintenance	Normal maintenance
X	1.32	2.83	0.98
Y	3.18	1.61	1.27

Step 3, convert the planned shop visit standard to coordinate, as shown in Table 2 and then use similar reasoning to cluster the planned shop visit products in accordance with the planned shop visit standard. Training results are shown in Figure 4, and the empirical research results are shown in Table 3 and Figure 5 (digit 1, 2, and 3 on the picture represents the classifications and grades, box stands for group centroid). Because the empirical analysis objects and data refer to planned shop visit products, the amount of data are relatively large, so this study gives out partial data of planned shop visit products information according to similar reasoning method and grade classifications determinants in Table 3, there exists three-grade classifications of normal, priority, and delay maintenance according to two dimensions named maintenance plan and technical support of maintenance map, similar reasoning theory and principles. For example, as for planned shop visit product 1, x dimension and y dimension are 1.353 and 1.461, respectively, similar reasoning interval range is $[0.01, 0.09, 0.90]$, whose grade classification belongs to normal maintenance; as for planned shop visit product 2,

Figure 4: Training effect.

Table 3: Grade determination of planned shop visit products based on similar reasoning (partly)

Planned shop visit products	x	y	Similar reasoning	Grade classification
1	1.353	1.461	[0.01, 0.09, 0.90]	Normal maintenance
2	2.209	1.334	[0.12, 0.93, 0.01]	Priority maintenance
3	0.668	2.006	[0.08, 0.04, 0.86]	Normal maintenance
4	1.451	4.341	[0.87, 0.01, 0.12]	Delay maintenance
5	0.608	1.330	[0.02, 0.06, 0.92]	Normal maintenance

Figure 5: Grade determination of planned shop visit products based on similar reasoning.

x dimension and y dimension are 2.209 and 1.334, respectively, similar reasoning interval range is [0.12, 0.93, 0.01], whose grade classification belongs to priority maintenance. Figure 4 reflects training effects and learning effects with the help of sample, give outs training goal and curve, points out the training outcome and efficiency, reduces learning and training cost, enhances learning and training quality and quantity according to product grade methods and standards. The sample of training effects and learning effects is the premise of heuristic decision and similar reasoning. Figure 5 classifies the planned shop visit products into three categories: clusters and grades of normal maintenance, priority maintenance, and delay maintenance according to x and y dimensions, similar connotation and characteristic, training effect, training sample, and training outcome with the help of similar reasoning method.

Step 4, use the ant colony algorithm to search for the best maintenance scheduling program. According to the number of the planned shop visit products, select 1,000 times as the iteration's times, and the number of ants dispatched to the scheduling is 100. α is 4, showing the importance degree of pheromone; β is 8, showing the importance degree of heuristic factor; the information evaporation coefficient ρ is 0.4; and pheromone increment coefficient is 14. In MATLAB 7.0 software, operation results

are shown in Figure 6. The left component of Figure 6 (x horizontal coordinate represents the technical support dimension, y horizontal coordinate represents the maintenance plan dimension) clearly gives the optimal heuristic scheduling scheme of maintenance products by similar reasoning, the right component of Figure 6 (x horizontal coordinate represents the times of iterations, y horizontal coordinate represents scheduling distances) shows the minimum and shortest scheduling distance of the scheduling scheme.

In summary, the key and important information on empirical analysis results and conclusion analysis of schemes are as follows:

- (1) According to the maintenance services data of planned shop visit products of Harbin Dongan Engine Co., Ltd., this study constructs maintenance map and the corresponding evaluation indicators system, maintenance map includes two dimensions of the maintenance plan and technical support, a maintenance plan consists of maintenance requirements and maintenance complexity, technical support consists of maintenance personnel, maintenance equipment, and maintenance capacity.
- (2) The core idea of the established model of this study is a similar reasoning theory, taking the maximization of learning effect and the minimization of restructuring loss as the objective function. It is considered that priority should be given to solve similar problems in multilevel maintenance operations [51,52]. Maintenance costs and maintenance time are reduced by means of learning effect on feedforward maintenance operations, and repair grade clustering of the similar reasoning and scheduling optimization of the heuristic algorithm is evolved from a similarity theory.
- (3) From the results, the classification of the current decision-making method varies, increasing the workload of management and maintenance staff, and the boundary between different categories is not very obvious, which will weaken the learning effect of maintenance staff when they repair the products.

Figure 6: Optimal heuristic scheduling scheme and the minimum, shortest scheduling distance for planned shop visit products by similar reasoning.

From Figure 5, it can be seen that the grade evaluation of the planned shop visit product which uses the similar reasoning based on the standard case can not only effectively control the classification quantity but also can enhance the clarity and accuracy of the boundary of the grade assessment, which is beneficial to the maintenance personnel to generate the learning effect.

- (4) At present, the usage of the heuristic algorithm to solve the multi-objective scheduling problem is a more effective way [48], the left component of Figure 6 gives the optimal heuristic scheduling scheme of maintenance products by similar reasoning, which provides the theoretical basis for the management decision-making. In addition, the right component of Figure 6 shows the minimum and shortest scheduling distance of the scheduling scheme, and the manager can also develop a maintenance schedule to provide operational tools for lean management.
- (5) Based on the maintenance services data of planned shop visit products of Harbin Dongan Engine Co., Ltd., this study uses a similar reasoning method combining with an ant colony algorithm to carry out the heuristic decision, determine the minimum and shortest maintenance scheduling distances. The enterprise should arrange maintenance schedules and schemes according to scheduling distances in the maintenance map, namely the enterprise should carry out the scheduling distances priority and classify the maintenance products into the grades and categories of normal maintenance, priority

maintenance, and delay maintenance, the shorter scheduling distances should emphasize on the high priority, the longer scheduling distances should emphasize the low priority.

- (6) Based on the maintenance services data of planned shop visit products of Harbin Dongan Engine Co., Ltd., this study uses similar reasoning method combining with the ant colony algorithm to carry out the heuristic decision, determine the minimum maintenance time and iteration times to enhance maintenance efficiency and maintenance satisfaction of customers, reduce maintenance cost. The enterprise should arrange maintenance time and iteration times according to maintenance and iteration times in the maintenance map, the grades and category clusters of maintenance products in the maintenance map, namely the enterprise should carry out the maintenance time and iteration time priority and classify the maintenance products into the grades and categories of normal maintenance, priority maintenance, and delay maintenance; the shorter maintenance time and iteration time should emphasize on the high priority, the longer maintenance time and iteration time should emphasize the low priority.
- (7) Similar maintenance products with similar characteristics of two dimensions named maintenance plan and technical support in the same position in the maintenance map have similar ascriptions and attributions. Based on the maintenance services data of planned shop visit products of Harbin Dongan Engine Co., Ltd., this study uses similar

reasoning methods to have three different product grades and classifications, normal maintenance grades and classifications correspond to many maintenance and repair products and priority and delay maintenance grades and classifications also correspond to many maintenance and repair products. After dealing with three grades and classifications of maintenance and repair products, this study generates optimal heuristic decision schemes, paths, patterns, and paradigms with the outstanding characteristics and attributes of the shortest and minimum maintenance time, iteration time and maintenance scheduling distances, economic performance, maintenance and repair priority, cost and efficiency processing procedures, the relationships of combination and configuration, and schemes arrangement. The enterprise should take the sequences and orders of the grade classifications of priority maintenance, normal maintenance, and delay maintenance in turn successively to improve the maintenance quality, efficiency, and schedule, lessening and decreasing maintenance and repair timetable and cost. In a word, using the heuristic algorithm can find a set of the shortest and most economical maintenance and repair scheduling program within the target range to help the enterprise complete all repair requests.

- (8) Set heuristic decision method based on similar reasoning and ant colony algorithm as contrast objects and comparing with other heuristic decision and optimization methods of BP network, RBF network, GRNN network, firefly algorithm, leapfrog algorithm, particle swarm optimization algorithm, genetic algorithm, fish school algorithm, and simulated annealing algorithm, the iteration times and maintenance scheduling distances of BP network, RBF network, and GRNN network are lower than the $3/4$ of the heuristic decision method based on similar reasoning and ant colony algorithm, the iteration times and maintenance scheduling distances of firefly algorithm, leapfrog algorithm and fish school algorithm are lower than $5/6$ of heuristic decision method based on similar reasoning and ant colony algorithm, the iteration times and maintenance scheduling distances of particle swarm optimization algorithm and genetic algorithm are lower than $3/5$ of heuristic decision method based on similar reasoning and ant colony algorithm, the iteration times and maintenance scheduling distances of simulated annealing algorithm is lower than $5/7$ of heuristic decision method based on

similar reasoning and ant colony algorithm, the above heuristic decision and optimization methods can all obtain the heuristic decision, some of them can not obtain the optimal heuristic decision results and form maintenance map, they also can not sort out the maintenance priority of planned shop visit products according to diverse product categories, clusters, and grades combining with similar reasoning factors and elements. Heuristic decision method based on similar reasoning and ant colony algorithm of this study can obtain the minimum, reasonable, and appropriate iteration time and maintenance time, form maintenance map by different dimensions, sort out the maintenance priority of planned shop visit products according to diverse product categories, clusters, and grades combining with similar reasoning factors and elements, which can achieve and realize the minimum and shortest maintenance scheduling distances of planned shop visit products. This study also uses numerical techniques to verify and demonstrate the empirical analysis results validity, the iteration times, maintenance times, and maintenance scheduling distances of the PLS-DEMATEL method and the extended DEMATEL method based on interval number are nearly close to heuristic decision method based on similar reasoning and ant colony; the above two methods can obtain the relatively optimal heuristic decision schedules and schemes, form maintenance map, and identify the key and reason factors of the heuristic decision of two dimensions named maintenance plan and technical support. Naturally, the above two methods require a few calculation time, calculation procedures, and complex principles formulae.

5 Conclusion

The present study is aimed at using the findings on the mechanism of human learning and reasoning and considers that there are some similarities between the planned shop visit products, giving out the heuristic decision of planned shop visit products based on similar reasoning methods. This study introduces the concept of “maintenance map,” which establishes maintenance map and model, chooses and extracts scale and evaluation indexes from the perspective of organizational quality-specific immune (the core element and

construction dimension of organizational quality-specific immune is organizational quality defense), adopts Matlab software, puts the maximization of learning effect and the minimization of restructuring loss as the objective function, establishes a heuristic decision model of planned shop visit products based on similar reasoning method, and draws repaired products' maintenance map based on the empirical data, and further uses similar reasoning to determine the level of maintenance and looks for the best scheduling plan in maintenance map by ant colony algorithm. Maintaining a high consistency maintenance method is not only conducive to enhance the learning curve which can reduce maintenance time, but also reduces the loss that occurred during the scheduling process due to the minimization of restructuring in maintenance equipment and staff. This study gives out the heuristic decision of planned shop visit products with the help of Ant Colony algorithm and computer simulation based on the similar reasoning method; the theoretical framework and empirical analysis will provide theoretical reference and practical guideline for maintenance map, heuristic maintenance schedule, and heuristic decision of planned shop visit products.

In this study, the problem of maintenance decision-making of automobile engine is solved from a similarity perspective, the planned shop visit products are organized according to the degree of similarity, and similar reasoning theory is used to assess maintenance grade of the planned shop visit product, which facilitates maintenance personnel to grade and dispatch and produces a better optimization effect of maintenance decisions, setting a good guide for maintenance decision-making [49]. The empirical analysis results of this study are consistent with the standpoints that organizational quality defense is the core factor in the quality management field of enterprise, quality is the life of enterprise [53–57], two dimensions named maintenance plan and technical support of maintenance map can be determined from the perspective of organizational quality-specific immune, and the quality and quantity of planned shop visit products are the attribute reflections and evaluation indicators of quality; furthermore, plan, technology, and technical innovation are the key factors of quality for planned shop visit products of the enterprise. Thus, ensuring the maintenance quality, enhancing maintenance efficiency, improving maintenance outcome, reducing maintenance cost, decreasing maintenance time, and scheduling distances of maintenance and repair products with the help of maintenance maps are all important for sustainable quality development and

quality maturity of the enterprise. However, this kind of index system based on similarity theory is not mature, when using the best scale method to reduce the dimension, there are still some shortcomings in the determination of the discrimination measure. Therefore, further research and improvement are needed.

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