# Research about Group Decision Support System for Technology Resources Allocation of Engineering Machinery Based on Information Entropy

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***Abstract*—As allocation of engineering machinery technology resources involves many group members and the collaboration between different regional organizational systems is poor, this paper constructs a new structure of group decision support system of engineering machinery technology resources allocating based on Web Services and introduces the decision-making frame and processing flow chart in details. Also, a consensus decision-making method is proposed based on the information entropy model in order to eliminate the conflict between group members, thus obtaining more reasonable technology resources allocation scheme with high consistency. Finally in the part of application, the support system for technology resources allocation decision-making of the engineering machinery industry in Hunan province is taken as an example to verify .**

***Index Terms*—engineering machinery, technology resources allocation, group decision support system**

## I. Introduction

In today's China, there is an increasing demand for the technological innovation service in clustering engineering machinery industry, it involves many factors such as allocation of human resources, R&D(Research and Development) fund, and technological equipments as well as control of R&D cost. However, the way to meet the demand is full of blocks, such as low resource utilization rate, poor collaboration, repeated construction, underdeveloped core competitiveness and excessive dependence on imported pivotal components. The solution to clear the blocks up lies on the optimization of the limited resources, that is, how to allocate and schedule the technology resources effectively has become the most important issue to be solved, which is not an easy task. As the Chinese engineering machinery industry has long been region segmented, multiple areas and deciders for allocating resources are referred. The deciders are usually with different backgrounds which may cause a lot of conflicts, so a quick and consistent decision among deciders for allocating resources is hard to obtain, inhibiting effective resource allocation.

Targeted at solutions to resolution for conflicts during the consensus decision making process, some work have been done, such as: Wang [1] introduced a dividing-multiplicator method for optimal distribution of the engineering machinery. Xu [2] focused to eliminate the group conflicts by clustering the similar deciders' preferences. Xu [3] proposed an organizational decision-making coordination model on the basis of Artificial Intelligence (AI) technology. Chen [4] proposed to use the entropy-based method which combined subjective judgments with objective situation to determine the weight coefficient of indexes, and then integrated the entropy coefficient into TOPSIS method to conduct reasonable evaluation. Targeted at the production resources allocation issue of the engineering machinery and utilizing the principle that information entropy model could gather useful information and eliminate the useless in the preferences of the deciders as well as the combined weighted operator, this paper proposes a consensus decision-making method for resources allocation to counteract group conflicts and reach a consensus on resources allocation. The plan of using decision-making model and information technology to realize technology resources allocation have shown to be effective.

GDSS (Group Decision Support System), which was proposed by DeSanctis [5], is an interactive computer system. It is conducive to solving structured or semi-structured problems by way of group decision making. Liu [6] discussed the object-oriented modeling of support systems for multi-criteria decision making


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(MCDM) in natural resource management and introduced the development of a DSS-based support system for water resources management. Hsieh [7] regarded resource allocation decision-making process as an unreliable multi-source & multi-sink flow network, which required in computing the optimal resource allocation for a single demand configuration. Ozdamar [8] proposed a Hierarchical Decision Support System (HDSS) for production planning which enables production planners to utilize complex and structured planning algorithms interactively for planning better. Chaminade [9] took the Bangalore Software Industry Cluster District in India as an example and studied the influences of Regional Construction of Innovation System on medium-sized and small enterprises within that region. He held that the construction of that system enabled the enterprises within that region to transform into information providers in the global value chain in the mode of low-cost competition, thus accelerating the upgrade in that region. Through field research of layout rules for elements of the innovation system in the region of Yamagata in Japan, Takeda, etc. [10] found that location of organizations at the nodes of regional innovation network was always at where there were relatively excellent infrastructures, especially where the transportation was convenient. Shen [11] provided an update review on the recent achievements in different areas, and discussed some key issues in implementing agent-based manufacturing systems such as agent encapsulation, agent coordination and negotiation, optimization, security and privacy, etc.. . Minder Chen [12] had developed a Web Services-based group decision support system called TeamSpirit to optimize group decision results, and conducted the application and assessment of that system. Chen [13] designed a kind of decision support platform framework ,which is appropriate for complex large group .The framework was applied to the preliminary planning of Youchou hydropower station. Zhang [14] established GASS, an open implemental platform for group decision discussion, and provided an instance about decision of an enterprise to open up new markets. Xu [15] used Multi-Agent to compound atomic models required to solve decision-making problems, thus forming a model plan for solving such problems, and they proposed a Multi-agent-based model management system for decision support system. Kang [16] established Fujian mulberry flood control decision support system by using the distributed technology of Web services and the artificial intelligence agent.

In the process of technology resources allocating, many enterprises are involved and the relationship between them is complex. So it's hard for traditional group decision support systems to meet the requirements for decision-making under complex environment. From the perspective of software implementation, this work develops a support system for engineering machinery technology resources allocating group decision based on information entropy and Web Services. Based on information entropy resource allocation collaborative decision-making model and a large number of historical and collaboration Real-time data, that system is designed to: (1)create and maintain the data warehouse and computing model, (2)support the task of technology resources allocation, (3)harmonizes benefits and eliminates conflicts between various groups through data storage technology in order to achieve the goals of creating resources allocation plan efficiently and providing powerful decision making support for ensuring technology resources allocation.

## II. Control Mechanism Of Group Decision-making On Mechanical Mechinery Technology Resources Allocation

### A. *Support Method*

Engineering machinery management is a huge system, of which technology resources allocation is an important part. As technology resources is a kind of resource which is rare but high in production and can be reused in the long run, its space allocation owns an far-reaching influence on social and economic development. Aiming at specific requirements of technology resources, the complex dynamic process in which decision makers can develop appropriate programs fast for technology resources allocation and distribution to minimize the cost and time and maximize distribution efficiency, involves human, material, financial resources, the environment, and time, etc. Meanwhile, as the technology resources deployment decision making boasts the characteristics of complexity, uncertainty, dynamic and timeliness et al., it's necessary to achieve the optimal allocation of resources, to coordinate the interests of various decision makers, to reflect the wishes of different members, as conflict between members is unavoidable. Therefore, during the decision-making process of engineering machinery technology resources allocation, research about conflict resolution has become an important part of the fast and efficient resources allocation program generated by the system.

Suppose A to be the demand point, i.e. where resources are needed, and set up goals & requirements for technology resources allocation and conditions of constraint according to the business environment, we can establish the index system $X^r$ for technology resources allocation decisions at location A, of which r represents the number of indicators. And suppose that there are n resource reserve points $A_1, A_2 \ldots, A_n$ in total, that for the k-th resource (0≤k≤r), $X_i$ represents demand quantity of that resources at point $A$ ($i = 1, 2, 3 \ldots, n$) while $X_i^{'}$ represents the reserve quantity of that resources at $A_i$ ($i = 1, 2, 3 \ldots, n$). Also suppose that $\sum_{i=1}^{n} X_i^{'} \geq X_i$ is conformed to, and set the time it takes to reach from $A_i$ to $A$ to be $t_i$ .

For the *k-th* (0≤*k*≤*r)* resource, *m* （ $m>0$ ） decision-making experts are assigned. And for *n* reserve points, *m* experts provide their suggestions on the deployment amount of *k-th* resource (0≤*k*≤ *r).* Assume that for the *i-th* rescue point, the allocation amount given by the *j-th* expert is $x_{ij}^{k}$ （*j*=1,2, … , *m*）, then the allocation amount of *k-th* resource from *n* rescue points under the advice of *the expert group* can be shown in the following matrix:

$$X^k=\begin{bmatrix} X_1^k \\ X_2^k \\ \vdots \\ X_n^k \end{bmatrix}=\begin{bmatrix} x_{11}^k & x_{12}^k & \cdots & x_{1m}^k \\ x_{21}^k & x_{22}^k & \cdots & x_{2m}^k \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1}^k & x_{n2}^k & \cdots & x_{nm}^k \end{bmatrix}. \quad (1)$$

The matrix above can be standardized by column as follows:

$$Y^k=\left(y_{ij}^k\right)_{nm}=\begin{bmatrix} x_{11}^k/\sum_{i=1}^{n}x_{i1}^k & \cdots & x_{1m}^k/\sum_{i=1}^{n}x_{im}^k \\ \vdots & \ddots & \vdots \\ x_{n1}^k/\sum_{i=1}^{n}x_{i1}^k & \cdots & x_{nm}^k/\sum_{i=1}^{n}x_{im}^k \end{bmatrix}. \quad (2)$$

To calculate the weight of the j-th expert for the k-th resource, the information entropy method can be used. The j-th expert's information entropy for the k-th resource is $E_j^k=-\frac{1}{\ln n}\sum_{i=1}^{n}y_{ij}^k\ln y_{ij}^k$ ; when $y_{ij}^k=0$ , $y_{ij}^k\ln y_{ij}^k=0$ . The j-th expert's weight of the k-th resource is:

$$\omega_j^k=\frac{1-E_j^k}{\sum_{j=1}^{m}\left(1-E_j^k\right)}. \quad (3)$$

For the k-th resource, the resource allocation amount in the i-th area given by decision group can be induced:

$$p_i^k=\sum_{j=1}^{m}\omega_j^k\cdot x_{ij}^k. \quad (4)$$

Then for the k-th resource, resource allocation amount of n rescue points in total given by decision group is:

$$p^k=\left[p_1^k,p_2^k,\ldots,p_n^k\right]^T. \quad (5)$$

Considering all kinds of resources, the resources allocation amount of n rescue points in total given by decision group is:

$$P=\left[p^1,p^2,\ldots,p^r\right]. \quad (6)$$

*B. Decision-making Process*

In realizing the description and definition of problems on engineering machinery technology resources allocation in system, several factors need to be addressed, such as the type of required resources, business environment of enterprises that need resources, deployment targets (time *t*, resources distribution point *n*), deployment requirements (the required amount $X_i$ ), deployment guidelines(fast, efficient) and conditions of constraints (the reserve of resources distribution point $X_i^{'}$ ) ,etc. The key to the success of resources allocation decision is that the description of the system is in accord with the needs and target of engineering machinery technology resources allocation.

For problems on decision of technology resources allocation, the description of resources demand, event attributes and decision parameters are involved. We can invocate problem-decomposition model and specify the scheme for problem-decomposition through Web Services. Premise is to ensure that the problem can be decomposed into a series of atomic decision indicators which can be given directly. In order to provide the foundation for problem solving, the logical relations of decision-making index should be defined and described, and then construct the solving method of each atom index and its parent index. Since logical relationship exists between decision-making indexes, all of the decision indexes and their logical relations constitute the index system of resource allocations decisions.

After $X^r$ is created, in order to create a standardized and structured interactive decision-making process for decision-making experts, as well as to reduce the complexity of decision-making, and at the same time to eliminate the conflicts of decision-making between experts and enhance the efficiency of decision-making, decision-making organizers assign experts to each decision index according to expert opinion, thus forming the decision-making expert task tree for $X^r$ . Decision experts invoke the data processing methods through Web services to conduct data analysis and comparison, and provide their individual decisions. For one single decision index, after all the individual decisions are submitted, the group decision matrix $X^k$ is formed. System invokes group decision making method based on information entropy model through Web Services to standardize $X^k$ , thus getting $Y^k$ , and gains the expert's weight $\omega_j(0<j\le m)$ through calculating, so as to get the allocation amount $p^k$ of this resource provided by the decision-making group. When all experts finish their decisions, system is recursive from bottom up through

decision system $X^r$, and gain the decision matrix $p$ of resources allocation in all regions, , thus building the optimal decision making program of that resources allocation problem. The flow chart of group decision on resources allocation is shown below in Fig. 1.

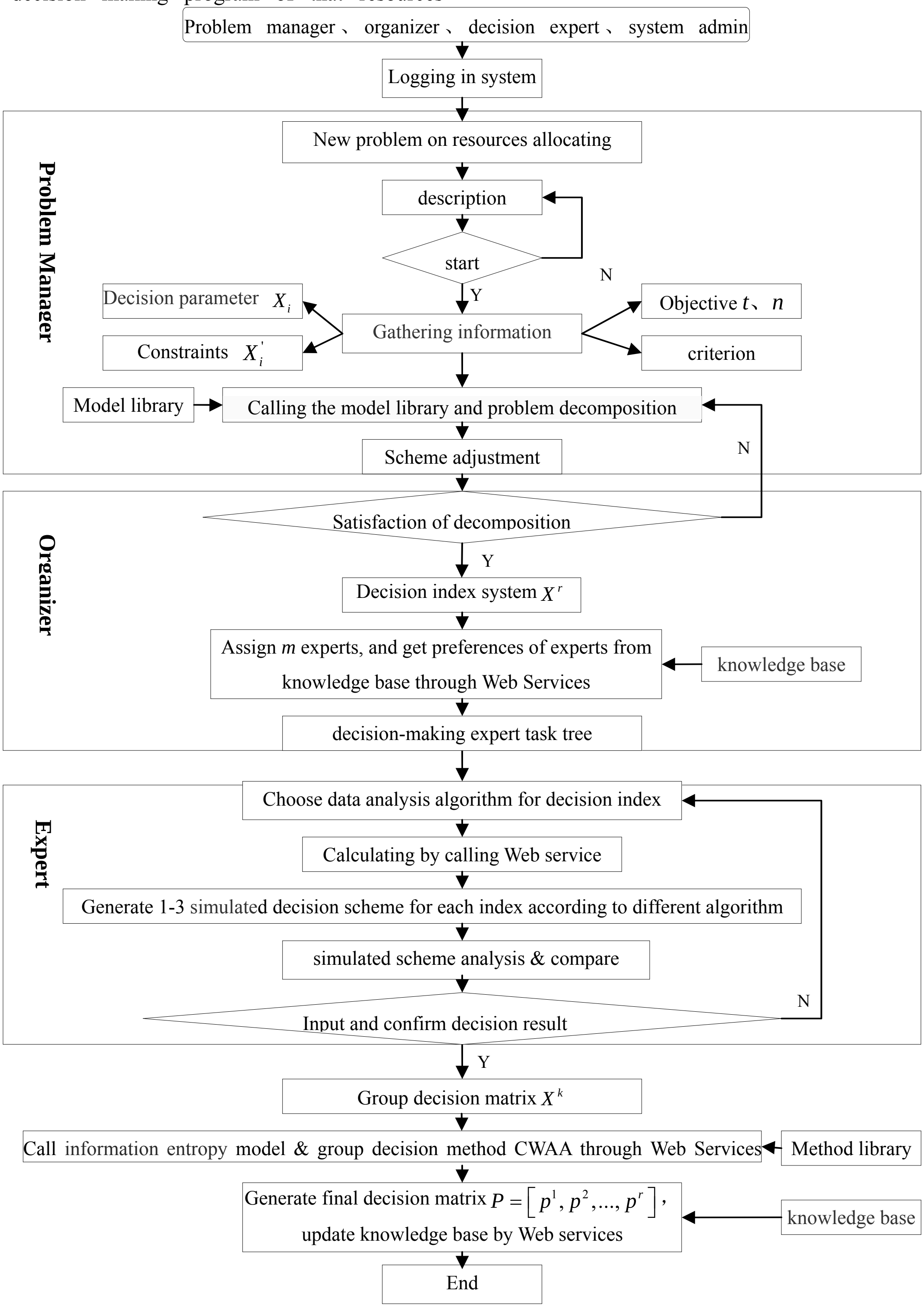



Figure 1. The flow chart of group decision on resources allocation.

## III. STRUCTURE DESIGN OF GROUP DECISION SUPPORT SYSTEM

Based on the above description of group decision design and system concept model, in combination with Web services and the characteristics of GDSS system, every individual decision resource is designed to be Web services distributed on the Internet so as to realize the cross-platform application of decision process. That makes it convenient for group members to make emergency decision under different network environment so as to be more efficient and rapid in decision scheme generation. The system architecture is shown in Fig. 2:

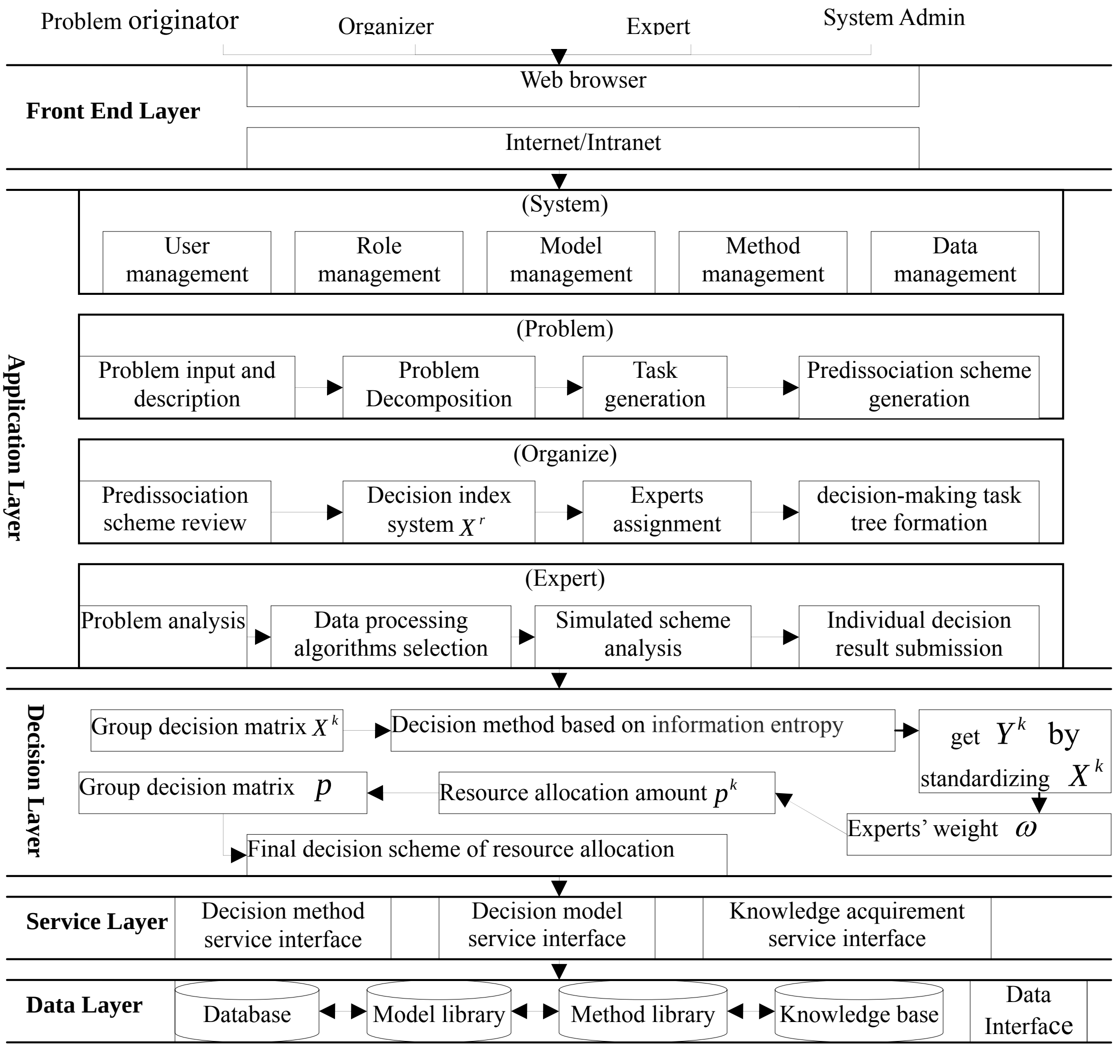



Figure 2. The architecture of GDSS.

Meanwhile, according to process description of group decision method and flowchart of the system, roles in the system could be divided into four types: decision problem manager, organizer, decision expert and system administrator. Each role has corresponding permissions:(1)decision problem manager is responsible for defining and describing resources allocation problem, and forming the decision index system $X^k$ for solving decision problem through man-machine combination;(2) the organizer can assign experts for the decision problems, and lead the group to reach consensus;(3) decision expert can read information on decision problem assigned to him and get individual decision results by invoking the corresponding data processing algorithm of the decision problem. On the basis of each experts' result can we get the resources allocation decision matrix $X^k$ of the group;(4) System administrator is responsible for model management, method management, role privilege, and data management, etc. of the whole system.

The decision-making system has four core modules of function: decision problem, decision organizing, decision expert, and system administration, each module could be described as follows:

(1)The Module of Decision Problem (Problem): the decision problem manager is in charge of this module. The users can determine the value of t、n、 $X_i$ and $X_i^{'}$ and do relative data entry by knowing about the scientific development, current conditions of resources requirement and reserve of scientific resources in relevant organizations at where resources are required.. After that, experts are organized to conduct structured decomposition on problems by calling decision models in the model library. Finally, the precalciner scheme of resources allocation problem will generate by collating the decomposition information above.

(2)The Module of Decision-making organization (Organizer): Firstly, after auditing the issue and decomposing it, the organizer would adjust and modify the decomposition scheme constantly until it is satisfying. And then the index system of resources allocation decisions $X^r$ would be formed. Secondly, the organizer would assign experts to the indexes according to background, professional direction and experience of each expert. Then the task tree of decision experts $X^r$ would be formed. Meanwhile, the organizer can adjust the result of the assignment in real time until the assignment is over.

(3)The Module of Decision Expert (Expert): the decision expert is responsible for this module, which involves problem analysis and decision-making of experts. Through analyzing such basic information of decision indexes as quality, space distribution, and mobility, etc., the expert invokes different data processing algorithm as required with the help of the decision-making system, and then provide an individual decision result after consulting the analog solutions in the system. Also, the experts can modify their own result after reading the results of other experts until the end of individual decision-making process. That is how the group decision matrix $X^k$ is formed.

(4)The Module of System Management(System):in this module, the system administrator is responsible for collection, sorting, classification, and entry of documents about resources allocation information, for data cleansing and integration. At the same time, the system administrator also take charge of updating knowledge base, model base and method library.

The system runs on the Intranet/Internet environment and builds the Browser/Server(B/S) structure by adopting the solution of ASP.NET 2.0 + SQL Server 2005 database. This system also sets up a stand-alone server as Web server and database server. Windows 2008 Server R2 64-bit server OS, Microsoft IIS 6.0 and Microsoft.NET2.0 are installed on the Web server, and Microsoft SQL Server 2005 Standard (including OLAP) database is installed on the database server.

## IV. APPLICATION

This section focuses on the allocation of technology resources on the integration platform of technology innovation service for engineering machinery industry in Hunan province. With the complexity of resources allocation in engineering machinery industry taken into full consideration, the technological resources database of engineering machinery industry in several regions of Hunan province was established after investigation of some relevant enterprises and consulting of vast literatures. Then a system simulation which centers on problem decomposition, decision-making organization and expert decision-making for the decision process of technology resources allocation in Hunan province is made.

Backgrounds: Engineering machinery industry, as an advantage industry in Hunan Province, has seen the formation of the engineering machinery industry cluster in Hunan centering on Zoomlion, Sany, and Intelligent, etc. Currently, Changsha Zoomlion is developing a hydraulic pressure speed stabilizer. However, as the manual labour, equipment, and materials could not meet the R&D demand, it is urgent to obtain scientific research personnel, technology equipment and R&D materials from relevant organizations. After discussion, the technology resources index system $X^r$ and the required amount $X_i$ is shown in Table I. According to engineering machinery enterprises and institution for scientific research of Changsha area and some other areas nearby, experts work hard to optimize the emergency allocation scheme. Emergency allocation of resources is a dynamic and multi-phase process, i.e. with the evolvement of technology and resources transportation, the resources is allocated unceasingly and the resources in areas nearby need to be used constantly. Hence, on the assumption that the earliest starting time of allocation does that change, the less is the amount of rescue stations put into that, the better .

TABLE I.
THE INDEX SYSTEM OF ENGINEERING MACHINERY TECHNOLOGY RESOURCES ALLOCATION IN CHANGSHA

| First-grade index | Code | Second-grade index | Amount of demand |
|---|---|---|---|
| R&D experts | X1 | Materials experts | 12 |
| | X2 | Machining specialists | 18 |
| Supply of R&D equipment | X3 | Dynamic mechanical thermal analyzer | 40 |
| | X4 | Dynamic load test cylinder | 30 |
| | X5 | Hydraulic pressure testing machine | 40 |
| Supply of materials | X6 | Hydraulic oil | 200 |
| | X7 | Piston | 100 |

The decision-making process for the allocation of technology resources is presented as follows:

(1) The decision-maker logs in the Decision making module, input the semantic description of the decision-making problems into the system by entering the type of the scarce resources, degree of scarcity,the demand amount of every resource, and the amount of reserves. Then, $X^r$ is established in an man-machine interactive way. Taking the hydraulic oil supply amount for example, the demand amount $X_i$ =200, the number of rescue station is [(n, t)]= [(Changsha,0.5),(Zhuzhou,1.1),(Xiangtan,1),(Yueyang,2),(Changde,2.1),( Hengyang,2.3)], and the corresponding arrival time $X_i^{'}$=[18,72,65,154,168,193], as shown in Table II: $A_i$ stands for the resources distribution station; $X_i$ stands for hydraulic oil reserves of each station; $t_i$ stands for the time took from each station to *A*.

TABLE II.
DATA ABOUT ALLOCATION ATATION

| $A_i$ | Changsha | Zhuzhou | Xiangtan |
|---|---|---|---|
| $X_i$ | 18 | 72 | 65 |
| $t_i$ | 0.5 | 1.1 | 1 |

| $A_i$ | Yueyang | Changde | Hengyang |
|---|---|---|---|
| $X_i$ | 154 | 168 | 193 |
| $t_i$ | 2 | 2.1 | 2.3 |

(2)After verifying $X^r$, the decision-making organizer consults the expert information and assigns experts to each atomic decision according to their experience and professional direction. Then the task tree of decision expert is formed. Taking the supply amount of coal for example, Fig. 3 shows the detailed assignment process of expert m=6.


Figure 3. The webpage of decision expert assignment

(3) Decision-making experts firstly know how to choose different data processing algorithm bases for analog computation (such as the fuzzy programming method with multiple objective) in the webpage of decision analysis by consulting the atomic decision indexes assigned to them. Then the decision support system automatically invokes suitable algorithm to calculate the corresponding reference value of those decision-making indexes and returned the values to experts. By comparing reference values, consulting the decision-making results made by other experts, experts adjust the decision suggestion constantly according to their own opinion and provide the individual result at last, as shown in Fig. 4.

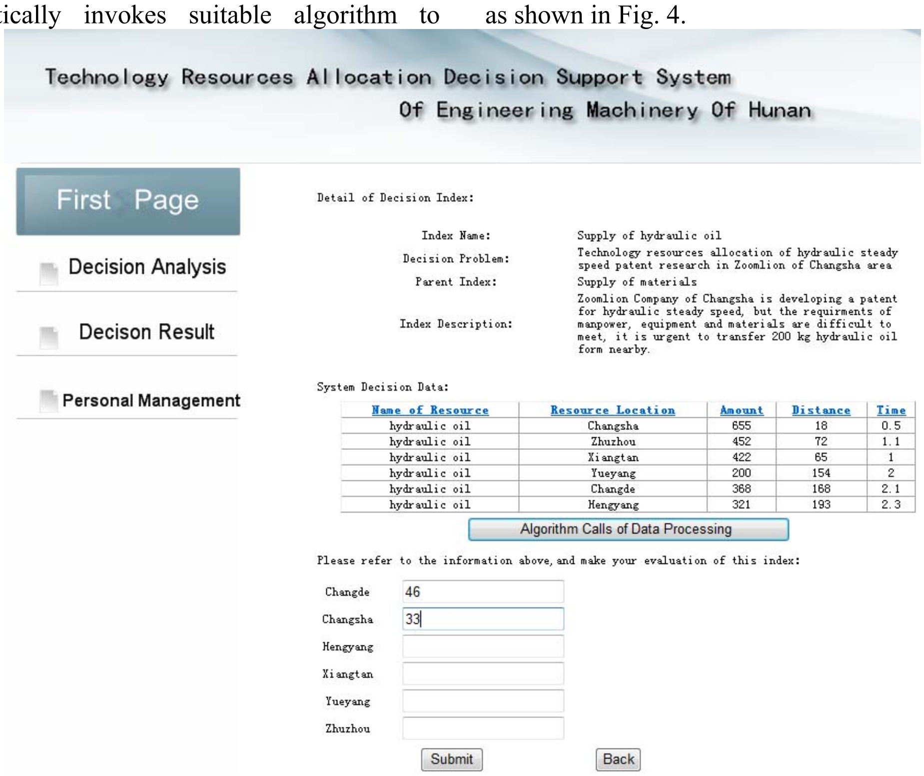
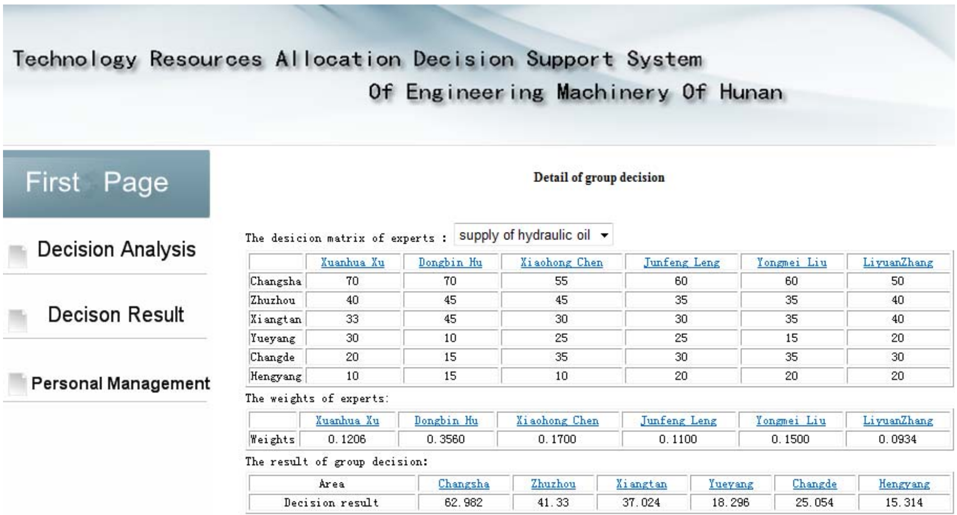



Figure 4. The result webpage of one decision-making expert

(4) After all the experts' individual decision results have been submitted, the group expert decision matrix for resources allocation is constructed. Taking the supply of hydraulic oil for example, the decision support system invokes the group decision-making method based on information entropy to combine group expert decisions into a resources allocation matrix

$$X^k = \begin{bmatrix} 70,70,55,60,60,50 \\ 40,45,45,35,35,40 \\ 30,45,30,30,35,40 \\ 30,10,25,25,15,20 \\ 20,15,35,30,35,30 \\ 10,15,10,20,20,20 \end{bmatrix}$$

, as shown in Figure 6. After $X^k$ is normalized, the expert's weight vector $w$ for the corresponding atomic decision index is got according to value of each expert's information entropy. And $\omega^k = [0.1206, 0.356, 0.17, 0.11, 0.15, 0.0934]$. Then according to the Equation: $p_i^k = \sum_{j=1}^{m} \omega_j^k x_{ij}^k$, the amount of resources allocated to six rescue stations are acquired, $p^k = [62.982, 41.33, 37.024, 18.296, 25.054, 15.314]$. Finally, the group decision results are obtained as shown in Fig. 5.




| | Xuanhua Xu | Dongbin Hu | Xiaohong Chen | Junfeng Leng | Yongmei Liu | LiyuanZhang |
|---|---|---|---|---|---|---|
| Changsha | 70 | 70 | 55 | 60 | 60 | 50 |
| Zhuzhou | 40 | 45 | 45 | 35 | 35 | 40 |
| Xiangtan | 33 | 45 | 30 | 30 | 35 | 40 |
| Yueyang | 30 | 10 | 25 | 25 | 15 | 20 |
| Changde | 20 | 15 | 35 | 30 | 35 | 30 |
| Hengyang | 10 | 15 | 10 | 20 | 20 | 20 |

| | Xuanhua Xu | Dongbin Hu | Xiaohong Chen | Junfeng Leng | Yongmei Liu | LiyuanZhang |
|---|---|---|---|---|---|---|
| Weights | 0.1206 | 0.3560 | 0.1700 | 0.1100 | 0.1500 | 0.0934 |

| Area | Changsha | Zhuzhou | Xiangtan | Yueyang | Changde | Hengyang |
|---|---|---|---|---|---|---|
| Decision result | 62.982 | 41.33 | 37.024 | 18.296 | 25.054 | 15.314 |

Figure 5. The group decision-making result of hydraulic oil supply amount

After all the experts completed their task of decision on technology resources allocation, index $X^r$, the decision support system conduct bottom-up recursion in that decision index system and construct the group resources allocation decision matrix $P$ for all the resources in all regions. And then the optimized group decision scheme for solving the resources allocation problem is achieved.

## V. Conclusion

Management of decision on allocation of engineering machinery technology resources is a dynamic interactive process with multi stage. By referring to relevant literatures both in China and from abroad, this paper has studied GDSS architecture which is based on information entropy and Web services, analyzed the detailed group decision-making process, determined the conceptual models and functional structure of the system, and introduced the critical technology for system implementation. Also, simulation was done to the system taking decision sub-platform of the integrated system for the engineering machinery technology innovation service of Hunan as an example, and the result turned out to be satisfactory, providing possibility for technology resources allocation of engineering machinery enterprises. However, as technology resources allocation in reality involves many factors, the model library, alternative library and expert library of the GDSS need to be expanded further; seeking for a more scientific group decision-making method, taking macro-control of the Government into consideration, and combination of the system with external information systems (such as resources reserve distribution system) would be our next work.

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