A Talent Laboratory Resource Supply Chain Model Based on Fuzzy Analytic Technology

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Abstract: This paper proposes a talent laboratory resource supply chain model for an educational institution to increase the integration, visibility and flexibility of the laboratory resource management. The proposed model utilizes a reasoning engine with fuzzy, parallel fuzzy rules, and de-fuzzy processes to decide the optimal purchase ordering quantity and the best constant stocks in the laboratory resource supply system. The fuzzy process takes the crisp input data through the characteristic function and maps the input data into its corresponding membership degree. The fuzzy rules are processed with different degree of membership and all rules in the system are processed before triggering an action. The de-fuzzy process takes each item's purchase ordering membership through the singleton output function and generates the corresponding crisp data. The proposed model allows users keying in their required experimental materials via the Web Site, uses the database management system to integrate all related information, and applies the fuzzy reasoning engine to generate the final purchase order reports to support the executor making the optimal decisions.
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1. Introduction

Nowadays, with the developed e-technology, educational institutions have gradually transferred their paper-based records into the computerized paperless form in order to increase departmental productivity, lower administrative costs, increase the process visibility of an official document, and support information analysis [1]. However, in spite of a great need of e-technology, Beheshtifar and Nekoie-Moghadam [2] stated that effective process on talent management for allocating sufficient resources is also an urgent issue for an institution to improve their overall performance. Besides, Xu, He, and Gen [3] also stated that an integrated management of the supply chain can reduce the propagation of undesirable events through the network and can affect decisively the profitability. Therefore, as driven by educational needs and enabled by information technology, the objective of this study is to propose an intelligent laboratory resource supply chain model to achieve the optimal performance and profit of an educational institution.

Figure 1 shows the paperless process of the laboratory resource supply chain at Electronic Engineering (EE) department of Kao Yuan University (KYU). As given in Figure 1, the departmental administrator (DA) will sends an e-mail in the end of the semester to ask teachers who have Lab. classes such as electronics Lab. and microcontroller Lab. and who manage Lab. facilities for listing next semester's required experimental resources. The DA then collects all the received lists and checks every resource's specification by human labors. If the received listed item is unclear or lack of the specification, the DA will make a call or send the e-mail to the teacher asking for the correct specifications.

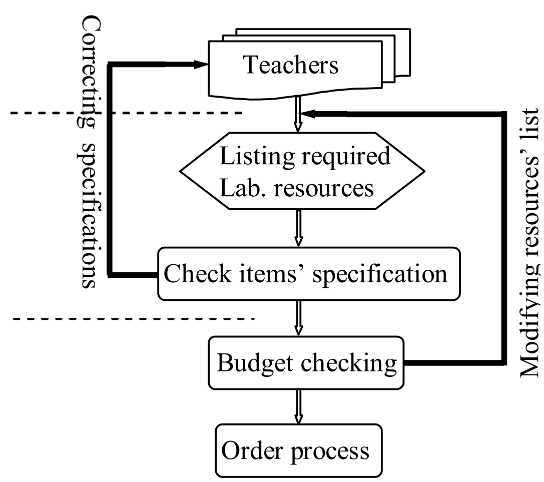

Figure 1. Paperless process of the laboratory resource supply chain

Generally, processing such laboratory resources' supply chain is often influenced by three factors, including: (1) the familiar degree of the administrator and the teacher on materials' specifications and resources' alternative choices; (2) the limited budget on purchasing the departmental experimental resources for a semester; and (3) the process time of the laboratory resources' supply chain. Therefore, this kind of the laboratory resource supply-chain process has the disadvantages of possibility of ordering wrong experimental resources, delaying the process time, thereby the lack of the experimental resources at the beginning of the semester, decreasing teaching quality, and dissatisfaction among students, teachers, and DA.

Laboratory resource supply chain planning system in an educational institution can be viewed as small/medium sized enterprise (SME) resource supply chain planning system which is an integrated software solution helping organizations to manage their key resources, including money, staff, products, customers and suppliers, more effectively and efficiently [4]. Several literatures [5-10] have applied artificial intelligence technology to improve the effectiveness and efficiency of supply chain management in an institution. Zarandi, Pourakbar, and Turksen [5] proposed a fuzzy agent-based model for reduction of bullwhip effect in supply chain systems. The proposed model can minimize the total cost and can suggest the reasonable ordering policies of a supply chain. Cheung, Cheung, and Kwok [6] presented a knowledge-based customization system with visibility for supply chain integration (KCSSI) which is developed based on the visualization of topologies, network analysis, and knowledge-based system to obtain quantified actionable information and formulating strategies for supply chain configuration leading the long term success.Aburto and Weber [7] proposed a hybrid intelligent system applying neural network concept and autoregressive integrated moving average (ARIMA) technology for demand forecasting. The proposed approach was compared with two different forecasting approaches, named Naïve and MLP models, and was implemented in Economax supermarket supply chain management system in Chilean, Japan. The results showed that the ARIMA model has the advantages of fewer sales failures and lower inventory levels. Symeonidis, etc. [8] incorporated a data mining technique into an organizational selling policy to reduce the company's cost and improve its service. The proposed method, as a recommendation engine, deployed supply chain and customer relationship management techniques to successfully fuse information to customers, suppliers, manufacturers and warehouses. It minimizes system-wide cost and satisfies service level requirements. Canavesio and Martinez [9] proposed a conceptual project-based SME network model using decentralized and autonomous organizational units, named as fractal, to achieve a high degree of flexibility to environmental changes. The model was implemented by logic programming language Prolog; the simulation results tell emergent behavior and constraints. However, the model like a multi-agent system is lack of the appropriate intelligent technology to integrate all fractal units and evaluate the organizational effectiveness and ultimately performance. To overcome this drawback, Wang, etc. [10] designed a Meta model as the core technology for integrating distributed relational database management systems with the backend of enterprise system developed by the software vendors. The proposed model aims to achieve enterprise resource sharing, shorten purchase time, and lower operation cost, which takes an on-line electronic purchase system as the example to demonstrate its efficiency and effectiveness.

Literatures [11-14] are four studies related to decision support systems. Padillo, etc. [11] developed a strategic decision support system for product allocation and major resources planning. Worley, etc. [12] developed an expert system generator, a neural network simulator, and a case-based reasoning module to provide answers for the users. Due to both supply chain decision support systems only specific to the enterprise's supply chain, they have the disadvantage of inflexibility. To overcome this weakness, Julka, etc. [13] proposed a unified framework which integrates different ERP elements such as the production processes and the associated business data and knowledge to model, monitor, manage, and analyze the business polices. Moreover, in order to rapidly response to a dynamic global market and satisfy frequently changing customer demands, Ni, etc. [14] proposed a configuration-based flexible reporting method to help managers make decisions, perform planning activities and communicate with partners, which allow users to generate reports for different companies by providing different sets of configurations.

References [15-21] evaluated some ERP models and their success and failure factors. Tan, etc. [15] proposed a methodology with activity-based metric measurement models to evaluate the performance of the process flows, including activity, product information, resource, cost, cash, and profit, within manufacturing enterprises. Sarkis and Sundarraj [16] discovered that approximately two-thirds of ERP systems are said to be failure. Evgeniou [17] investigated that organizations are stuck on either suffering from lack of information visibility across enterprise or suffering from information flexibility. The study suggested that an ERP planning system should provide visibility of the ERP system to external constituents via Web linkages, standardization of internal processes, and important information technology systems to support market needs. Sun, etc. [18] utilized quantitative information to evaluate the cost, planned schedule, and goal achievement, which stated that effective use of enterprise resource planning systems is a critical success factor for many small manufacturing enterprises. Arnold [19] discussed the largely ignored behavioral impacts of enterprise systems' implementation and integration, which revealed that how the benefits will actually materialize from an inter-organizational perspective has received little attention. The study suggested that future research on enterprise systems should include (1) experimentation that focuses primarily on judgment and decision making at the individual level and improvements in organizational performance and (2) triangulation methods that integrate case research, surveys, and cross-sectional field studies. Moreover, Maropoulos, etc. [20] stated that the integration of the supply chain should focus on the early stages of product development where the majority of product lifecycle cost is decided. Sun, etc. [21] also suggested that system, service and information quality are most important successful factors.

In order to improve the drawbacks as described above, the authors propose an intelligent laboratory resource supply chain model to increase the visibility and flexibility of the laboratory resource supply chain process. The proposed model designs a resource database management system and utilizes parallel fuzzy reasoning information technology to achieve the optimal performance and profit. The proposed helps teachers and DA to familiar the resources' specifications and their alternative choices; checks the correctness of departmental received resource list; and provides the best performance of Lab. resource supply chain planning system. If there is something wrong on any step of the process, the system immediately informs the teacher and the DA to make a change or make an alternative choice. The process integration links functions with information, resources, and people, thereby improving internal communication, collaboration, and coordination.

In the following, Section 2 describes the proposed laboratory resource supply-chain model. The experimental results are shown in Section 3. Finally, the conclusions and future works are summarized in Section 4.

2. Laboratory Resource Supply Chain System

Figure 2 illustrates the process integration of the laboratory resource supply chain model, which consists of six steps with five units, including fractal units, web-based supply chain planning system, departmental administrator (DA), general affair, and vendors. The roles of each unit are described followed by the six steps of the laboratory resource supply chain process.

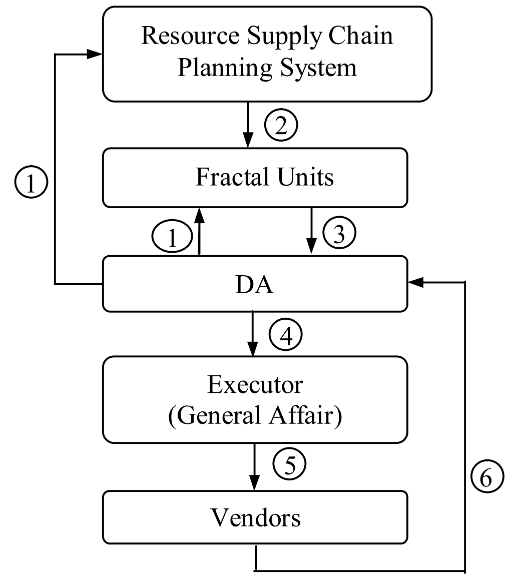

Figure 2. Process integration of the laboratory resource supply chain model.

2.1. Six Steps of the Laboratory Resource Supply Chain Process

Step 1: The DA requests for the tender by sending an e-mail to every fractal unit. Meanwhile, he or she will set the related parameters, including courses' titles, available lab resources, and people with the privilege accessing Lab. resource supply chain planning, and store them as records in the database management system.

Step 2: Every fractal unit submits Lab. resource proposal to the network based resource supply chain planning system via the Web Site.

Step 3: After received Lab. resource proposals from every fractal unit, the network based resource supply chain planning system collects and organizes all the received information; the system then generates final proposal of purchasing order reports for each laboratory and send them to the DA.

Step 4: After received final proposal reports, the DA makes final decisions based on the limited budget and the quantities of available resources; he or she will find three vendors with the best buy qualification in the market and send the decision results to the faculty who is in charge of purchasing Lab. resources in the general affair unit at KYU.

Step 5: The executor of purchasing Lab. resources will collect all the received Lab. resource ordering reports received from each DA at

KYU. If all the ordering reports are correct, he/she chooses one of the best buy qualified vendors and output final purchasing order reports to the chosen vendors.

Step 6: After received the purchasing order reports, the vendors will contact each DA to know the deadline for sending the Lab. resources to the department.

2.2. Roles of Each Unit in the Process Integration

(1) Fractal units: The teachers who have Lab. classes such as electronics Lab. and microcontroller Lab. and who are in charge of managing laboratory's instruments and facilities.

(2) Department administrator: The administrator, the faculty in charge of EE departmental laboratory resource supply chain planning system, periodically updates the newest each Lab. Resource status and fractal units stored in the database management system.

(3) Executor at general affair unit: The administrator, the faculty in charge of university supply chain planning system, collects all the resource ordering reports and outputs final purchase order decision to the specific quantified vendors for each department at university.

(4) Vendors: The companies provide the best buy of laboratory related instruments, facilities, and experimental materials.

(5) Network based resource supply chain planning system: The information integration software links functions with information, resources, and people for a departmental laboratory resource supply chain planning system. The aim of the software is to improve internal communication, collaboration, and coordination as well as achieve the best performance and profit. In order to gain the best profit of the system, the proposed system aims to minimize the whole cost of Lab. resource stock. Specifically, the economic ordering quantity should be optimized and the whole semester cost of purchase is defined as:

Whole semester cost of purchase (DCQ)
= Whole semester budget of Lab. resources (NB)
+ Lab. available stock (RS)

where D is the semester demand of certain resources, C is the cost of unit ordering, and Q is the economic ordering quantity. N is the student number at the department and B is the budget for a student; both of them are constant. R is the available resources and S is the quantity of available stock.

The proposed system includes three parts: the database management system, parallel fuzzy reasoning engine, and purchase order reporting system, as described in the following.

2.2.1. Database Management System

Figure 3 illustrates the schema of the entity relational database management system, which includes entities and attributes of entities related information in the database. As shown in Figure 3, the entity set contains entity name, entity identification, office location, entity e-mail, and entity phone number; and it has three attributes, including proposal, key and help. The attributes of the proposal are such as course name, Lab. name, item name, item identification, item specification, etc.; the key attributes store each entity's username and password to ensure teachers accessing the system securely; and the help attributes provide the information, such as item lists, specification lists, examples, etc., to help teachers proposing the required experimental resource.

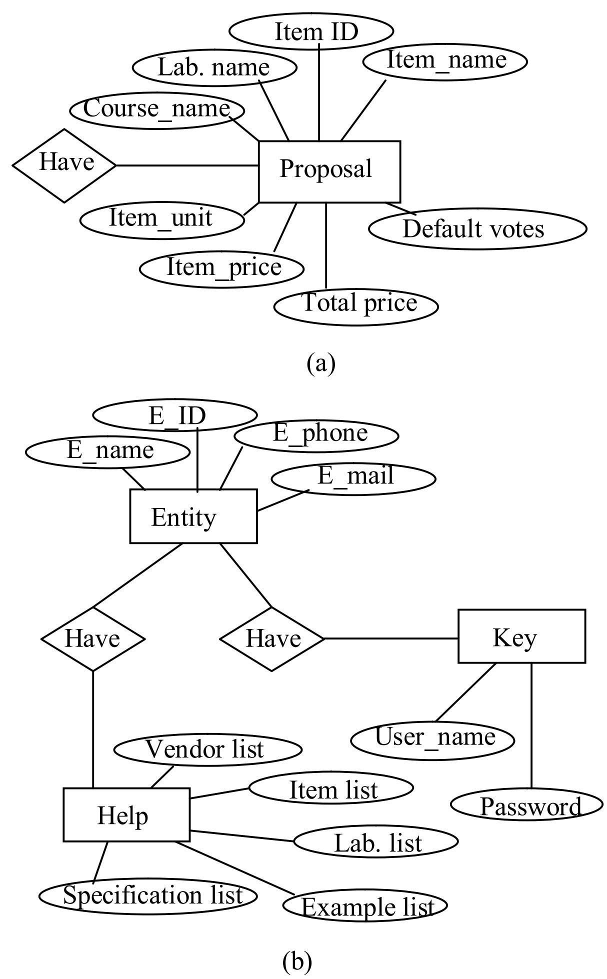

Figure 3. Schema of the entity relational database management system.

2.2.2. Parallel Fuzzy Reasoning Engine

The reasoning engine process consists of three processes, fuzzy, parallel fuzzy rules, and de-fuzzy as described in the following.

(1) Fuzzy: It takes the crisp input through the characteristic function and maps it into the fuzzy data, membership degree of the input data. In this section, the trapezoid membership function is applied to measure the membership degree of the input data as given in the Fig. 4.

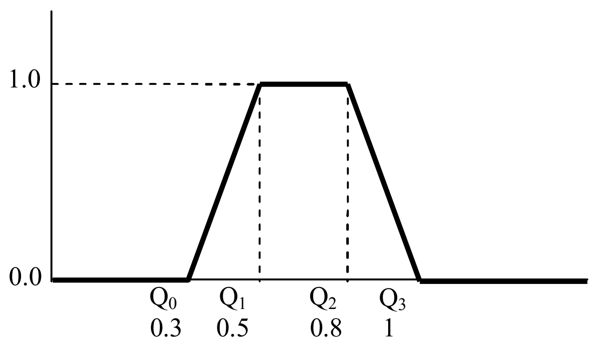

Figure 4. Trapezoid membership function.

,where function *F*(Q) is defined as

$$f(x) = \begin{cases} 0 & ; Q < Q_0 \\ \dfrac{Q}{Q_1 - Q_0} - \dfrac{Q_0}{Q_1 - Q_0} & ; Q_0 < Q < Q_1 \\ 1 & ; Q_1 < Q < Q_2 \\ \dfrac{-Q}{Q_3 - Q_2} + \dfrac{Q_3}{Q_3 - Q_2} & ; Q_2 < Q < Q_3 \end{cases}$$

As shown in Figure 4, the fuzzification maps crisp input data into four fuzzy sets, Low($Q \le Q_0$), High($Q \ge Q_3$), Medium Low($Q_1 < Q < Q_2$), Medium High($Q_2 < Q < Q_3$).

(2) Parallel fuzzy rules: Parallel fuzzy rules means every rule will be processed with different degree of membership and all rules in the system will be processed. The defined rules can be used for deciding the optimal economic ordering quantity, thereby increase the performance and profit. In addition, all the rules are simply set based on three fuzzy operators: disjunction (FuzzyOR), conjunction (FuzzyAND), and negation (FuzzyNOT), as given in the following.

FuzzyOR = MAX (A, B). For example, High OR Medium High = MAX (1, 0.8) = 1

FuzzyAND = MIN (A, B). For example, High AND Medium High = MIN (1, 0.8)=0.8

FuzzyNOT_A = 1-A. For example, NOT Low = 1-0.3=0.7

Following gives the example of the defined degree of membership fuzzy rule:

EX1: Degree_Purchase_Item
= MIN ((1-degree_Low), degree_High)

The parallel fuzzy rules are

If (budget is high) AND (item is needed) AND (available stock is low) then 100% Purchase,

If (budget is high) AND (item is needed) AND (available stock is medium low) then 80% Purchase,

If (budget is high) AND (item is needed) AND (available stock is medium high) then 50% Purchase,

If (budget is high) AND (item is needed) AND (available stock is high) then 0% Purchase, etc.

Therefore, the final values of process rules can be 100% Purchase=0.5; 80% Purchase =0.6; 50% Purchase=0.3; 0% Purchase=0.2.

(3) De-fuzzy: It takes each Degree_Purchase_ Item's degree of membership through the singleton output membership function and maps it into a specific crisp data. The singleton output membership function is defined as

$$output = \frac{\sum_{i=1}^{n} \mu_i x_i}{\sum_{i=1}^{i=n} \mu_i}$$

where u is the degree of membership and x is the final value of processed rules.

2.2.3. Purchase Order Reporting System

Table 1 shows the purchase order format, which includes item number, item name, specification, quantity, unit, price, total price, department, order data and notes. The generated purchase orders can be directly used by the DA to make the final purchase order and initiate a purchase process.

Table 1. Purchase order format.

No	Name	Spec	Qua.	Unit	Price	Total Price	Date
1	Transis	9012	100	pc.	5	500	09/12/1
2	Microc .	8951	100	IC	40	4000	09/12/1
3	Capac.	1u	200	pc.	2	400	09/12/1

3. Experimental Results

Figure 5 illustrates the system structure of the web-based user interface of Lab. resource supply planning system. As shown in Figure 5, a member can send the proposal and an administrator can send the request tender, output the reports, and set the parameters via the web-page. The proposed database management system has been implemented by using the following software and hardware.

(1) Operating system: Microsoft Windows XP Professional
(2) Web Server: Apache Tomcat 5.5.7
(3) Programming Language: Java 2 SDK v.5.0 and JSP
(4) Database management: MySQL 5.0
(5) Homepage: Dreamweaver and Flash

Figure 6 shows the web-based user interface of Lab. Resource database management system built at EE department of KYU. As shown on the bottom of the main homepage in Figure 6(a), there are three clicks, including News, Member login, and Message, used to access the Lab. Resource database management system. If a user wants to know the latest news of the Lab. Resource management, he/she can click "News" icon; or a user wants to leave a message, he/she can click "Message" icon. Figure 6(b) shows the member login homepage which allows user keying their user name and password to access the system to keying their proposals. Table 2 summarizes the definitions and countermeasures of four weaknesses, including invisibility, inflexibility inefficient, and nonprofit, existing in the current Lab. resource supply chain planning system at EE department of KYU.

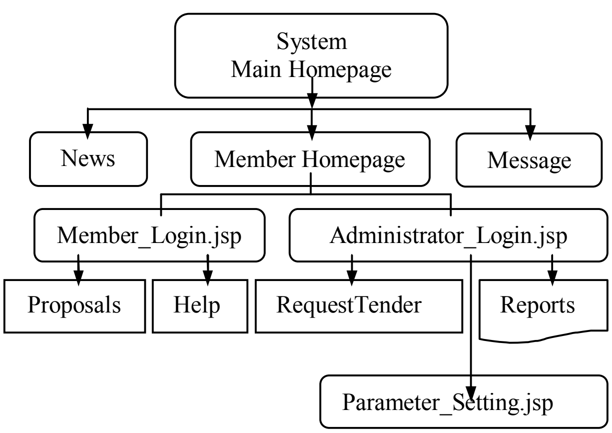

Figure 5. System structure of the Web-based user interface.

Figure 6. Web-based user interface; (a) Main homepage; (b) Member login user interface.

Table 2. Countermeasures of four weaknesses existing in the current Lab. resource supply chain planning system

Weaknesses	Improving Principles
Invisibility	Allowing users keying their required Lab. resources via the Web Site
Inflexibility	Constructing a database management system to collect and organize all Lab. resource related information
Inefficient	Decreasing paper and human resources' consumption and allowing information shared among different departments and individuals
Nonprofit	Supporting strategic decision making and information analysis with fuzzy reasoning engine

4. Conclusions

An intelligent laboratory resource supply chain model has been proposed in this study. The main contribution of the proposed model is to establish client-server relationship between supply chain managers and the teachers who either have Lab. courses or are in charge of Lab. resources. Compared to the existing methods, the proposed model supports four distinctive advantages: (1) increasing departmental productivity by allowing information shared among different departments and individuals; (2) supporting strategic decision making and information analysis by using fuzzy reasoning engine; (3) increasing the process and information integration, visibility and flexibility by allowing users keying their required Lab. resources via the Web Site and building a database management system to collect and organize all Lab. resource related information; (4) improving internal communication, collaboration, and coordination by linking functions with information, resources, and people.

This work can be extended to apply radio frequency identification tags [22-23] on each item of laboratory resources for decreasing the processing time and providing more effective and efficient stock management.

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