Expert Systems with Applications 29 (2005) 272–290

Expert Systems with Applications

www.elsevier.com/locate/eswa

Design of a knowledge-based logistics strategy system

Harry K.H. Chow[a], K.L. Choy[a,*], W.B. Lee[a], Felix T.S. Chan[b]

[a]Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[b]Department of Industrial and Manufacturing Systems Engineering, University of Hong Kong, Hong Kong, China

Abstract

Traditionally, the formulation of logistics strategies to execute various logistics services is done by human experts. In this paper, a knowledge-based logistics strategy system (KLSS) is designed in helping them to support the logistics strategy development stage by retrieving and analyzing useful knowledge and solutions in a timely and cost effective manner. The proposed knowledge-based system, which is suitable for usage in Hong Kong/Pearl River Delta region, enhances the effectiveness in formulating logistics strategies by integrating techniques like data warehouse, on-line analytical processing, multi-dimensional database management system and case-based reasoning. Through applying KLSS in Eastern Worldwide Company (EWW), resource utilization is maximized and work efficiency is greatly reduced.

Keywords: Logistics strategy; Knowledge-based system; Data warehouse; On-line analytical processing; Case-based reasoning

1. Introduction

Logistics service providers are professionals that serve clients like manufacturers, raw material suppliers, distributors, retailers, and shippers within the supply chain. The pressure on logistics service providers in operating a business is getting heavy due to the continuous increase in demand of clients. It is therefore necessary for logistics service providers to formulate business strategies from the knowledge perspective in order to keep distinctive competitiveness advantage in such a changing market environment (Davenport, Jarvenpa, & Beers, 1996). Logistics strategy planning is a complex process that requires an understanding of how the different elements and activities of logistics interact in terms of trade-offs and the total cost to the organization. Furthermore, it is always a challenge for logistics strategy planners to develop a series of logistics strategies for different clients, integrating manpower, facilities and workflow in the logistics strategies together to compromise with other clients' logistics strategies. Currently, logistics strategy planners usually rely on a collection of knowledge within the organization to formulate a strategy. In general, organizational knowledge is divided into two main categories: namely, experimental knowledge and analytical knowledge (Kim, Yu, & Lee, 2003).

As illustrated in Fig. 1, based on data and information such as the stock keeping unit (SKU), the dimension and weight of SKU, and the kinds of logistics services requests, provided by clients, the goal or direction of logistics strategy is initially constructed. Next, the content of logistics strategy is formulated by strategy planners who seek appropriate knowledge, retrieve similar past cases and modify them to fit the given situation.

In fact, logistics strategy planners always make bias judgments on logistics strategy formulation based solely on their experience. In addition, it is difficult for them to acquire, retrieve and manipulate various types of organizational knowledge without help of decision support systems. Hence, there seems to be no systematic approach for logistics service providers to capture the relevant knowledge for logistics strategy formulation.

Many logistics strategy planners are now using decision support systems to support logistics strategies formulation. However, most of them are data-driven rather than knowledge-driven. Hence, these techniques are incapable of retrieving knowledge at strategy design stage.

In such sense, there is a need of knowledge-based systems (KBS) that can collect, transform and store the organizational knowledge to support the stage of

* Tel.: +852 2766 6597; fax: +852 2362 5267.
E-mail address: mfklchoy@inet.polyu.edu.hk (K.L. Choy).

0957-4174/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2005.04.001

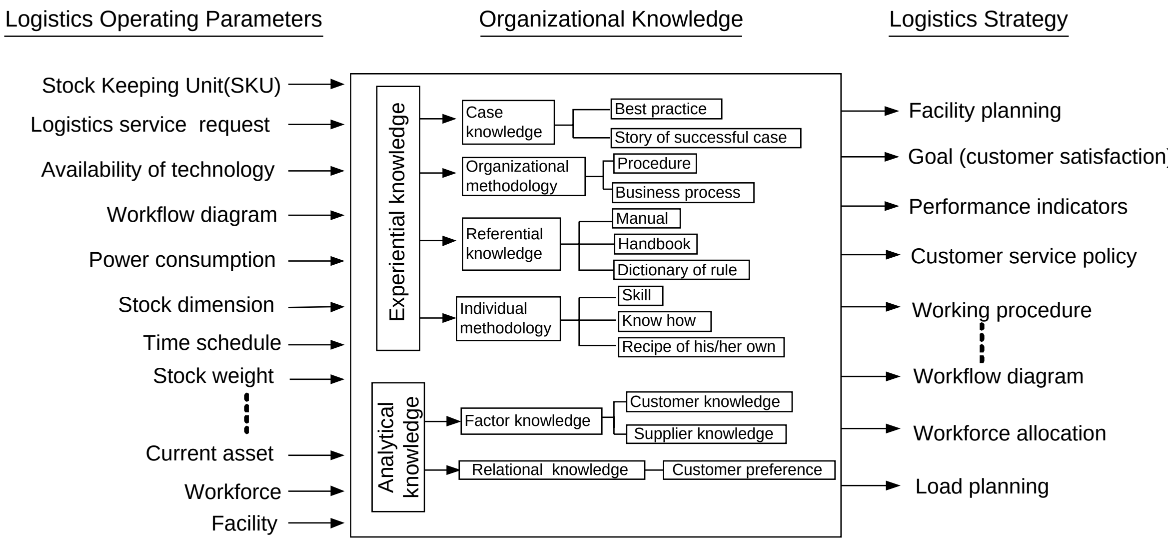

Fig. 1. Current logistics strategy planning process.

formulating logistics strategy in a systematic way. According to Wiig (1994), the definition of KBS is human centered, which highlights the facts that KBS have their roots in the field of artificial intelligence (AI) and that they attempt to understand and initiate human knowledge in the computer system. Liao (2003) categorized numbers of KBS researches and its applications. As shown in Table 1, it is found that there is no research related to the formulation of logistics strategy.

In this paper, a knowledge-based logistics strategy system (KLSS) is presented. This is a hybrid system to explore important attributes for case retrieval and matching process in a case-based system. The aim of this system is to effectively retrieve useful prior cases to assist logistics service providers in planning a cost-effective as well as a high-customer satisfactory-level logistics strategy among their clients. In order to develop a flexible and timely data accessing framework for the system, the combination of data warehouse, multi-dimensional database management system, online analytical processing (OLAP) and case-based reasoning (CBR) technologies is proposed. Whilst there are adequate publications about the data processing of CBR models, there is only a little literature related to the seamless integration of the data warehouse, multi-dimensional database management system, online analytical processing (OLAP) and case-based reasoning (CBR) model to develop an effective system to formulate logistics strategies.

This paper is divided into six sections. Section 2 is a description of the changes in the current logistics operating environment, and an explanation of the importance of managing relevant data and related information in the process of formulating logistics strategies. Data management techniques and CBR technology will also be discussed and their suitability in the formulation logistics strategy illustrated. In Section 3, the knowledge-based logistics strategy system (KLSS) is explained, while a case study of implementing the system in Eastern Worldwide Company Limited is discussed in Section 4. The results and a discussion on the findings are listed out in Section 5. Finally, the overall conclusion about the use of KLSS is made in Section 6.

2. Review of related studies

2.1. Current logistics operating environment

Since 1990s, the environment of logistics has changed greatly because of global integration and the gradual shortening of lifecycles of products. The mode of production in enterprises has changed from the traditional mass production mode led by products into the mass customization production mode to facilitate increasing

Table 1
Knowledge-based system and applications (extracted from Liao, 2003)

Knowledge-based system/ applications	Authors
Knowledge representation	Cauvin (1996) and Kim et al. (2000)
Petroleum industry	Cauvin (1996)
Human resource management	Martinsons (1977)
Database	Knight and Ma (1997)
knowledge engineering	Wielinga et al. (1997)
Manufacturing	Kang et al. (1998)
Quality management	Stein and Miscikowkski (1999)
Design	Lee and Lee (1999)
Military	Liao (2000, 2001)
Agriculture	Kim et al. (2000) and Fleurat-Lessard (2000)
Risk assessment	McMeekin and Ross (2002)
Microbiology	McMeekin and Ross (2002)
Project management	Tian et al. (2002)

global market competition. Srinivasa (2001) pointed out three main reasons of such revolution.

2.1.1. Change of manufacturing strategy

In the past, logistics was recognized as a distinct function with the rise of mass production systems. Since 1990s, the Japanese philosophy of distributed manufacturing and lean manufacturing has become the key technique which is widely adopted around the world. Consequently, the logistics operation is forced to change in order to fit such new Japanese manufacturing strategy. As a whole, logistics has become an extremely complicated process in which expert knowledge is required.

2.1.2. Change of customer demand

Business environment as a whole is becoming extremely volatile. As product life cycle becomes shorter, manufacturers can no longer push their products down the supply chain easily. On the contrary, it is the consumer who pulls the products along this supply chain. Price and quality are no longer sufficient to thrive in this market. As speed to market and flexibility of the supply chain become the winning criteria, logistics management has grown much more complex in order to satisfy these conditions simultaneously.

2.1.3. Globalization

As enterprises expand their markets beyond national boundaries, the need for more sophisticated services like multi-modal transport and international trade rules compliance increases. Hence, redesign of logistics operation is essential in order to achieve greater efficiency and effectiveness on these issues.

These issues revealed the complexity of logistics management in that traditional logistics operation which includes large quantity of stock storage and distribution cannot fulfill the real time, flexibility logistics service demand among the supply chain parties. Moreover, since logistics network has became more complex, it takes time to make critically decision in resource allocation and work task arrangement accurately. In such senses, a variety of researchers have examined the usage of various decision support systems (DSS) to solve a specific set of related logistics operating problems. Fung and Ren (1994) defined decision support system (DSS) as a viable strategic weapon that can help to shorten such time by aiding the planner to formulate logistics strategies in the area of planning and management of operation task. Hokey and Sean (1994) proposed an integrated decision support system (IDSS) that links worldwide communication and distribution networks among the parent company, its foreign business partners, and third-party logisticians in order to cope with globalization of business activities problem includes duplicated data, communication, resource allocation and transactional logistic operation. Moreover, a strategic decision-making model based on the analytical network process (ANP) to assist management in determining with which third party logistics provider to partner in the reverse logistics process has addressed (Meade & Sarkis, 2002). With regard to the pressure of fast delivery of small batches with minimized transportation cost, Vannieuwenhuyse and Pintelon (2003) presented a multi-criteria decision making tool (MCDM) to support logistics decision makers on the transportation mode selection process. These decision support systems help logistics service providers improve the functions of logistics operations like warehousing, transportation and human resources management and provide specific information for their client on marketing issues.

Srinivasa (2001) proposed a business intelligent (BI) tool in helping logistics service providers in achieving strategy formulation. The BI tool comprises data warehousing, OLAP and its related supporting system, which analyzes data collected from various sources and then converts it into actionable information. By providing a unified view of the entire supply chain, this tool can help improve the functioning of basic 3PL services like transportation management, warehousing and inventory management. It can also help 3PLs improve their own internal organizational functions like human resources and financial management.

In summary, the common trait of these decision support and business intelligent tools contains certain data management software like data warehouse, OLAP and multi-dimensional database management system (MDBMS) to store and explore the essential data in ways that are decision-oriented.

2.2. Data management software

2.2.1. Data warehouse

Data warehouse is a large-scale storage facility of data (Stein & Dahr, 1997). It was originally envisioned as a separate architectural component that converted and integrated mass of raw data from legacy, other operation systems and external source (Humphries, 1999). According to Inmon (1992), data warehouse is not just a large data storage database; it has also taken a much broader role. The data warehouse is a collection of integrated, subject-oriented databases designed to supply the information required for decision-making.

2.2.2. On-line analytical processing (OLAP)

OLAP is data manipulation software for decision making application by providing service for accessing, analyzing and viewing a large amount of data with high performance and visibility without predefined query (Kenan Technology, 1995). According to Dayal and Chaudhuri (1997), the typical operation performed by OLAP software can be divided into four aspects:

- Roll up (increase the level of aggregation);
- Drill down (decrease the level of aggregation);

- Slices and dice (selection and project);
- Pivot (reorienting the multidimensional view).

Data warehouse and OLAP are interconnecting with each other for decision making purpose, where data warehouse is responsible for data storage and handling, and OLAP captures stored data to form valuable information for decision making.

As OLAP application provides users with a multi-dimensional view of the data analyze, their operations need special and customized support.

2.2.3. Multidimensional database management system (MDBMS)

MDBMS is a multidimensional model which is implemented to provide a multidimensional environment in order to support the OLAP application. It acts as a data retailer which complements data warehouse architecture by getting data from a (relational) data warehouse and organizes it into star schema in order to provide fast response time to OLAP application (Jarke & Vassiliou, 2000). The star schema creates multidimensional space out of relational tables. It joins the single dimension tables with one another. This forms a multidimensional analysis space within the relational database. A star schema consists of one central fact table and several dimensional tables. A central large fact table holding measures, and a number of much smaller dimension tables normally characterize star schemas. The fact table contains the primary information in the data warehouse. Each dimension table contains information about the entries for a particular attribute in the fact table. It could be imagined that these dimensional tables act as plan gluing together fact tables to form a data cube (William, 2000).

So far, the decision support and business intelligent tools which contain certain data management software as stated in Srinivasa (2001) and other researchers only provide actionable information. Further actions such as logistics strategy development still rely on experienced logistics planners. It seems that the quality of logistics strategies and the efficiency of formulating strategies can be improved by case-based reasoning technology.

2.3. Case-based reasoning (CBR)

CBR is an AI problem-solving approach which contains a feature which is capable of learning and reusing knowledge. According to Choy, Lee, and Lo (2003), CBR is a problem-solving technique in which complements the solution, acting as a memory of past cases which can be consulted in order to identify similar cases for the new problem. This process is similar to the mechanism used by humans for the analysis of new situations. The human expert in the applicant's selection uses his/her previous acquired experiences as a valuable tool to explore the new scenario. The previous situations form the main source of knowledge for an expert in the hiring process. An old similar episode may serve as inspiration for a new solution. Aamodt and Plaza (1994) describes CBR as a cyclical process comprising the four 'Res', including:

- Retrieve the most similar case;
- Reuse the case(s) to attempt to solve the problem;
- Revise the proposed solution if necessary;
- Retain the solution as part of a new case.

The case is a free data format containing words, numbers and symbols to represent solutions and a state of affairs. As case is a free data format, its storage and retrieval method is different from general data storage. The case is stored in a case base with a set of attributes. These attributes are indexes to facilitate case retrieval. During case retrieval, CBR engine is based on a set of attributes to locate similar cases to deal with similar problem. Besides, it also reveals that the more important the cases, the larger number of indexes have to be used to record the case. If the case is not indexed; the retrieval time would increase, affecting case retrieval efficiency eventually. As concluded by Watson (1997), case indexing setting is important for efficient case retrievals. Currently, two common case retrieval methods, namely nearest neighbor method and inductive indexing method, are widely adopted.

(i) The nearest neighbor method lets the user retrieve cases based on a weighted sum of features in the input cases that match the case in the case library. Every feature in the stored or old cases and the degree of match of each pair is computed. During the case retrieval process, each feature in input case is compared with the corresponding features of past cases. Using the matching function, the degree of match of each pairs is calculated. Based on the important assigned to each dimension, an aggregate match score is then computed. The higher score cases will be ranked as first priority in problem solving before the lower score cases are used. Although this method performs efficient retrieval, building a hierarchical index needs the supervision of an expert during the case—authoring phase.

(ii) Inductive indexing method is basically a search for similarities among a series of instances and then categorizing them based on those similarities. Induction an algorithm such as a Classification and Regression Tree (CART) determines which features have best discriminate cases, and generates a tree-typed structure to organize the case. An induction tree is then built upon a database of training cases. This approach is very useful when a single case feature is dependent upon others. However, the case searching speed is slow as it generally looks for similarities over a series of instances in order to perform accurate case retrieval.

In order to enhance searching speed and accuracy at the same time, Wess, Althoff, and Derwand (1993) proposed a retrieved mechanism named *k–d* tree integrating two case retrieval techniques. This proposed retrieved mechanism composes the niches of two case retrieval techniques.

Within a *k–d* tree, the case is first organized into tree-type structure with specific indexing. A decision tree is then built by inductive indexing for case indexing. When a new case arrives, a decision tree is applied to retrieve the past cases that are similar to the new case. The retrieval time of using this inductive index tree is much faster when comparing with that using the nearest neighbor method, resulting in a faster case retrieval process. Therefore, inductive indexing is usually in the retrieving cases, after the list of cases is retrieved, the nearest neighbor method is then applied to find the best match case.

Many publications had gone through the studying of AI application and business intelligent tools in the areas of planning (Kolodner, 1993), diagnosis (Watson & Abdullah, 1994), process control (Koegst, Schneider, Bergmann, & Vollrath, 1999) in large and small–medium sized enterprises. For example, Choy, Lee, Lau, Lu, and Lo (2004) proposed an online based supplier relationship management system which integrated CBR technology in the area of supplier selection. However, the research area related to integration between these technologies on logistics operation areas is rarely addressed. The domain of this research is to propose a knowledge-based logistics strategy system through the integration of OLAP, MDBMS, Data warehouse and CBR to formulate logistics strategy as shown in Fig. 2.

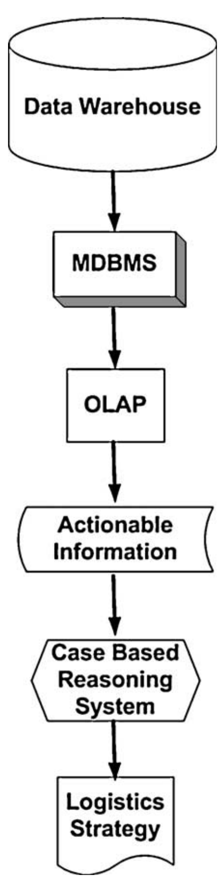

Fig. 2. Knowledge-based logistics strategy system.

A review of publications indicates that many research activities are done on data warehouse, OLAP, MDBMS and CBR. However, the research area related to integration between these technologies on logistics strategy formulation has not been addressed. In addition, the domain of this research is to propose a knowledge-based logistics strategy system by integrating the OLAP, MDBMS, Data warehouse and CBR. The capabilities of the system are evaluated and discussed through a trail run implementation at a local logistics service company.

3. Knowledge-based logistics strategy system

The knowledge-based logistics strategy system (KLSS) described in this paper integrates the niches of CBR with OLAP technology to assist logistics service providers on formulating logistics strategies resulting in the achievement of the highest possible customer satisfaction level with optimum operating cost. KLSS operates by first capturing raw data, discovering hidden data pattern and then transmitting into CBR engine to retrieve past similar cases with accurate and valuable knowledge for supporting logistics strategy planning.

3.1. System architecture of KLSS

The architecture of KLSS composes five modules to perform four stages of developing new client's logistics strategy as illustrated in Fig. 3. Module 1 is a web-based platform for data entering and system access function. Module 2 is composed of OLAP software and data warehouse on supporting valuable data for potential case retrieval purpose. The case retrieval engine in Module 3 plays the role on retrieving potential cases against the input case specification. The new logistics strategy case creation is performed by case adaptation module in Module 4. The case repository in Module 5 composes of two types of case library to store a number of previous stored cases and new successful cases.

3.1.1. Module 1—Web-based platform

The web-based platform is the user interface of the system to enter logistic service specification and access logistics service function.

3.1.1.1. Logistics service specification entry. The client's logistics service specifications such as the parameters of stock keeping units (type, size, color, quantity, dimension and weight) and relevant logistics service requests are transferred through the web-based platform to the data warehouse.

3.1.1.2. Accessing of system functions and output display. The function of OLAP, case-based retrieval engine and case-based adoption module are operated through

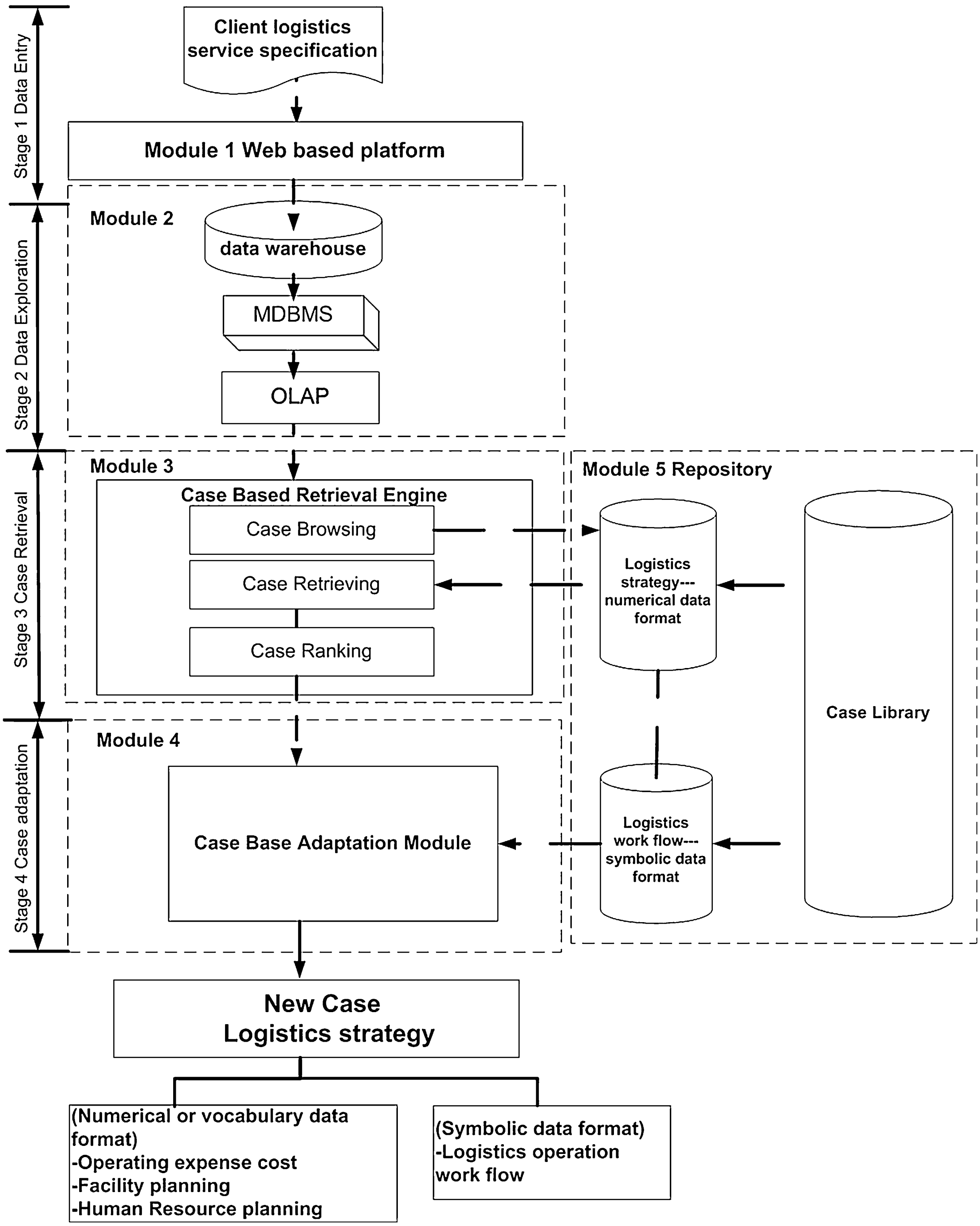

Fig. 3. The system modules of knowledge-based logistics strategy system (KLSS).

the web-based platform. Besides, it also displays the output of the system, such as new cases of logistics strategy. The web-based platform contains a number of web pages which are constructed by HTML language. As HTML is a programming language that represents static information only, a server scripting language named ASP (Active Server Page) is added into the web page to make it dynamic and interactive. In such case, data is transmitted through the web-based platform to the data warehouse.

3.1.2. Module 2—OLAP software and data warehouse

This module is responsible for supporting potential attributes for the case retrieval process. It is done by three embedded sub-modules including data warehouse, OLAP software and multidimensional database management system (MDBMS).

3.1.2.1. Data warehouse. It is a large database that stores all data from different operating systems in an enterprise and external sources. The data stored in this database belongs to integrated data which is obtained from internal and external data sources. The internal data is extracted from the enterprise's operating system, while external data comes from the enterprise's business partners such as suppliers and clients. In general, the data of performance index and specifications made by customers extracted from the data warehouse and used as attributes for case retrieval purpose.

3.1.2.2. OLAP software. It is used for retrieving 'attributes' from the data warehouse. According to the logistics service specifications, the OLAP software retrieves, analyzes, filters and extracts relevant data without predetermined query.

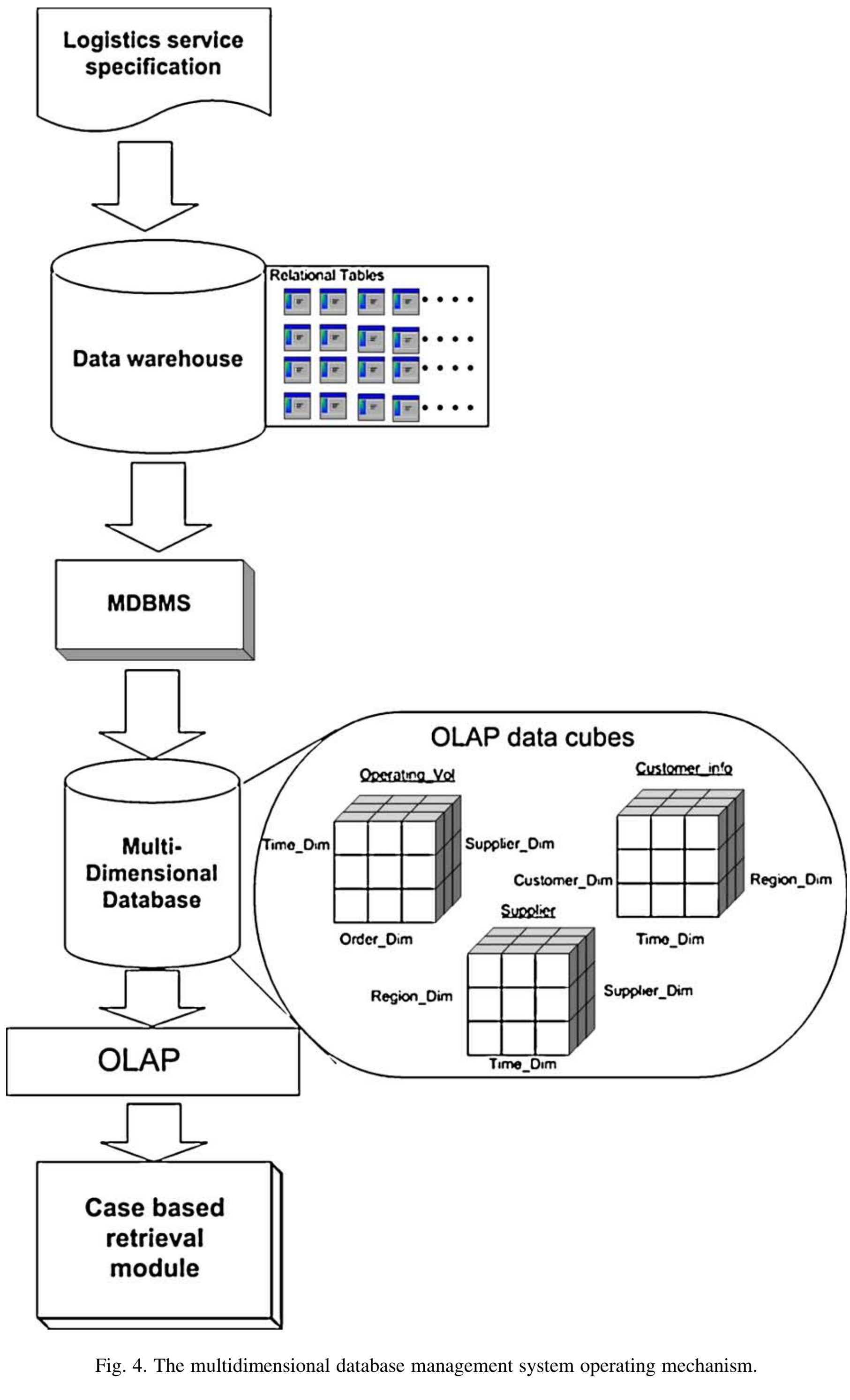

Fig. 4. The multidimensional database management system operating mechanism.

3.1.2.3. Multidimensional database management system (MDBMS). It supports the OLAP software operation. Fig. 4 shows the data which are stored in relational data warehouse is first extracted by MDBMS and then located into the multidimensional data structure like *n*-dimensional cube format. This database cube can facilitate a large amount of data analysis and explore the hidden relationship of data. The extracted data is used for attributes for case retrieval.

3.1.3. Module 3—The case retrieval engine

The case-based retrieval engine retrieves past cases for solving current problems. This module consists of three sub-modules to extract relevant case, namely, case browsing, case retrieving and case ranking module.

3.1.3.1. Case browsing. In this sub-module, after receiving user's enquiry of specifications, the tree structure of the case library is browsed for suitable cases. These cases contain a set of attributes, indexed as a checkpoint, matching the specifications of the input case. As illustrated in Fig. 5, the case is structured in the form of a tree with different layer from top (general operation area) to bottom (specific operation of workflow). The case retrieval engine searches the specific workflow diagrams through these indexes. Once a new case workflow is created, it is saved in the case library.

3.1.3.2. Case retrieving. In this sub-module, a list of potential cases is retrieved after matching with the specification of new input case by means of the *k–d* tree indexing method.

3.1.3.3. Case ranking. In this module, a pre-determined weight (w_i) is added to the factor (f_i) using the nearest neighbor method as shown in Eq. (1)

$$\frac{\sum_{i=1}^{n} w_i \operatorname{sim}(f_i^I, f_i^R)}{\sum_{i=1}^{n} w_i} \tag{1}$$

where

w_i weight of feature I
sim similarity function
$f_i^I f_i^R$ the values of feature f_i in the input.

According to the degree of similarity, a list of ranked cases is generated and sent to the case adaptation module for creating a new case.

3.1.4. Module 4—The case base adaptation module

The process of new case creation such as edition, combination, detection or addition of past cases is performed in this module. For example, a new logistics strategy is created by modifying the existing workflows in the retrieved case. By changing the design of its workflow, the demand for manpower is adjusted correspondingly. In doing so, a new logistics strategy is created.

3.1.5. Module 5—Case repository

This module is for storing cases of logistics strategies in free data format. Normally, a case contains a set of attributes represented in words and numbers to describe an affair or a problem. The case of logistics strategy not only contains word and number descriptions, but also allows workflow diagrams. This module is composed of two types of case library, namely, general data typed case library and symbolic case library for storing cases.

3.1.5.1. General data typed case library. It stores a number of past cases in the form of a tree structure case database. Cases in the library are made up of three parts: case number, case indexes and strategy sets. The case number assigned by the KLSS acts as a unique identification of cases in the case library. The case indexes are built up by a set of attributes that describes the affair in the case. This set of attributes is an identity for the case retrieval engine to match and retrieve cases.

3.1.5.2. Symbolic case library. It is a sub-library of the general data case library which stores data in symbolic data format such as workflow diagrams. The case is made up of three parts, including a case number, a case index and a workflow diagrams. The case number is the one that has been assigned in the general data typed case library. During the retrieval process, the case retrieval engine retrieves the case workflow diagrams according to the retrieved case number.

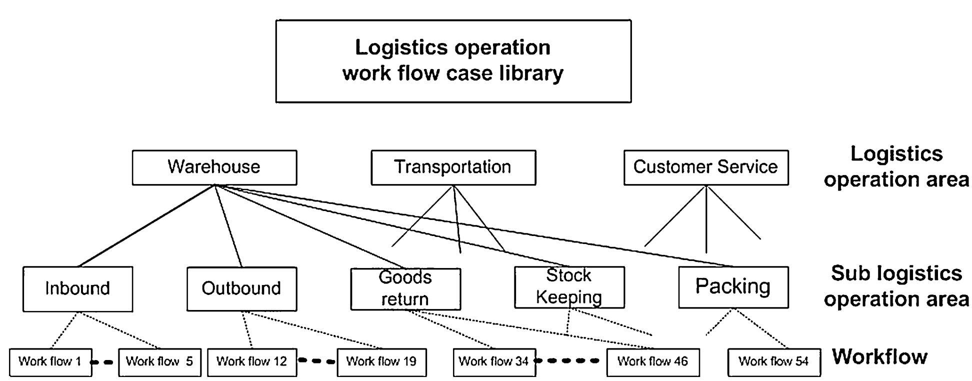

Fig. 5. Logistics operation workflow case library.

4. Case study

In order to validate KLSS, it was tested in Eastern Worldwide Company Limited (EWW). The company is one of the largest Hong Kong based freight forwarding and logistics companies which provides multi-modal services that provides business of all sizes with a wide range of logistics business like door-to-door transportation, warehousing and distribution, international freight forwarding services, logistics consultation and project management services. Its office with a well-equipped multi-functional warehouse of 300,000 square

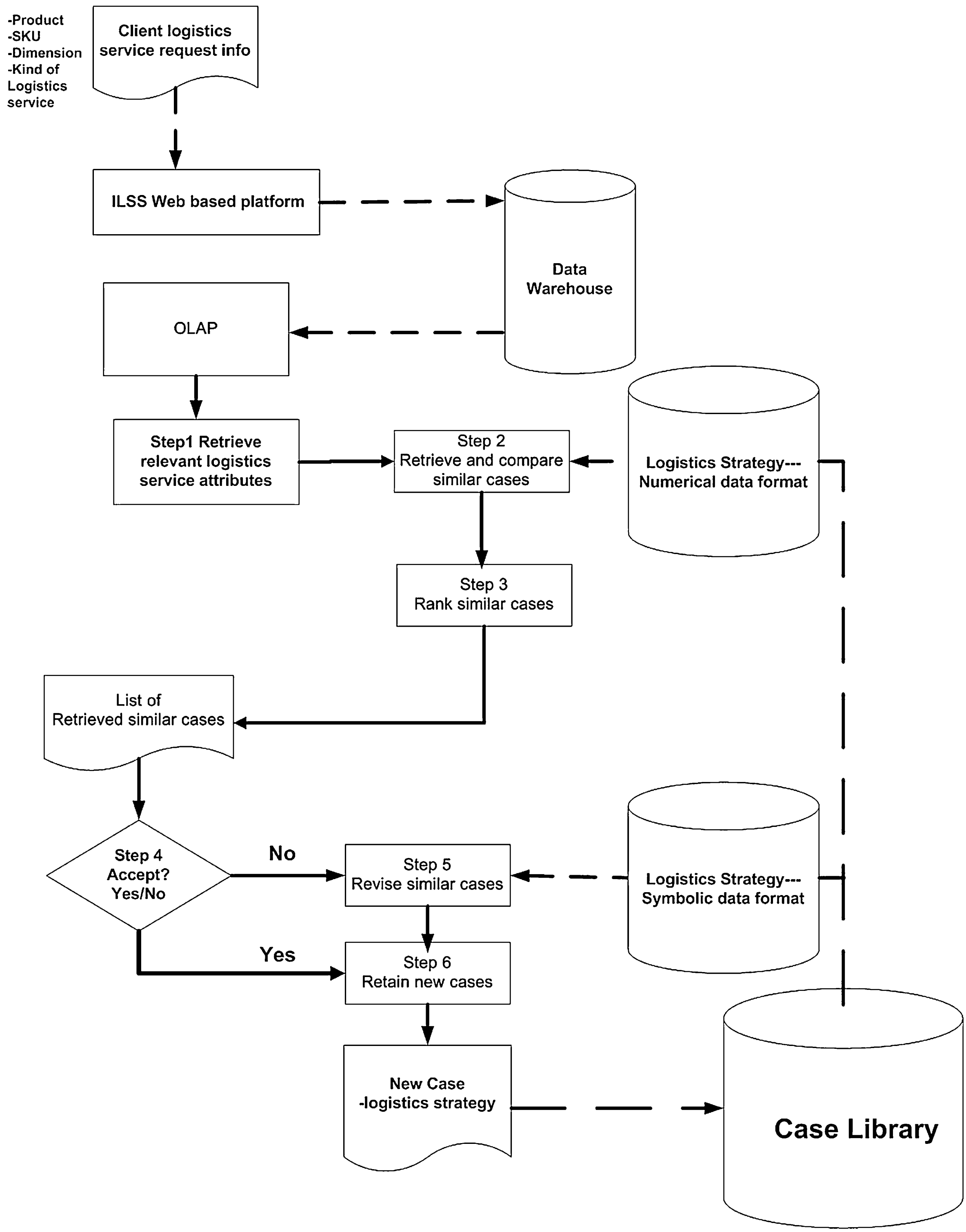

Fig. 6. The process flow of KLSS.

feet is located in Hong Kong. EWW employs around 800 professional and experienced staff to handle daily logistics operation. Its visions are to provide quality, cost-effective and reliable logistics solutions to clients utilizing the professional workforce, modern fleet of vehicles and extensive transportation network with integration of advanced information technology systems.

To enhance competitive advantage in the logistics industry and maintain a leading position in market share, the company needs to provide more various value-added services to their customers who process more complicated tasks than other logistics service providers in Hong Kong. EWW provides a wide range of services from extremely large-scale projects to very precision-technology projects. For the managerial staff, they are facing a number of problems during the implementation of logistics strategies in these projects. They include:

- Inaccuracy in the prediction of operation task and cost;
- Changes in specification of project;
- Special tasks are planned to serve different clients' service requirements.

Therefore, EWW has decided to adopt KLSS for improving the current process of logistics strategy development. The system framework is built in Visual Basic as the main development program, together with OLAP and data warehouse to help managerial staff in planning logistics strategies for different projects. Fig. 6 shows the operating procedures of KLSS in formulating a logistics strategy for the provision of electronic parts made by Philips corporate Limited. Six steps are operated in KLSS, starting from the retrieval of relevant attributes to the retaining of useful cases. In Step 5 of revising similar cases, the case-adaptation module of KLSS has five stages to revise the retrieved cases.

4.1. Step 1: Retrieve relevant logistics service specifications

Fig. 7 shows the web-based platform of KLSS, by selecting appropriate buttons, logistics service specifications such as SKU dimension, SKU dimensions, SKU weight, SKU

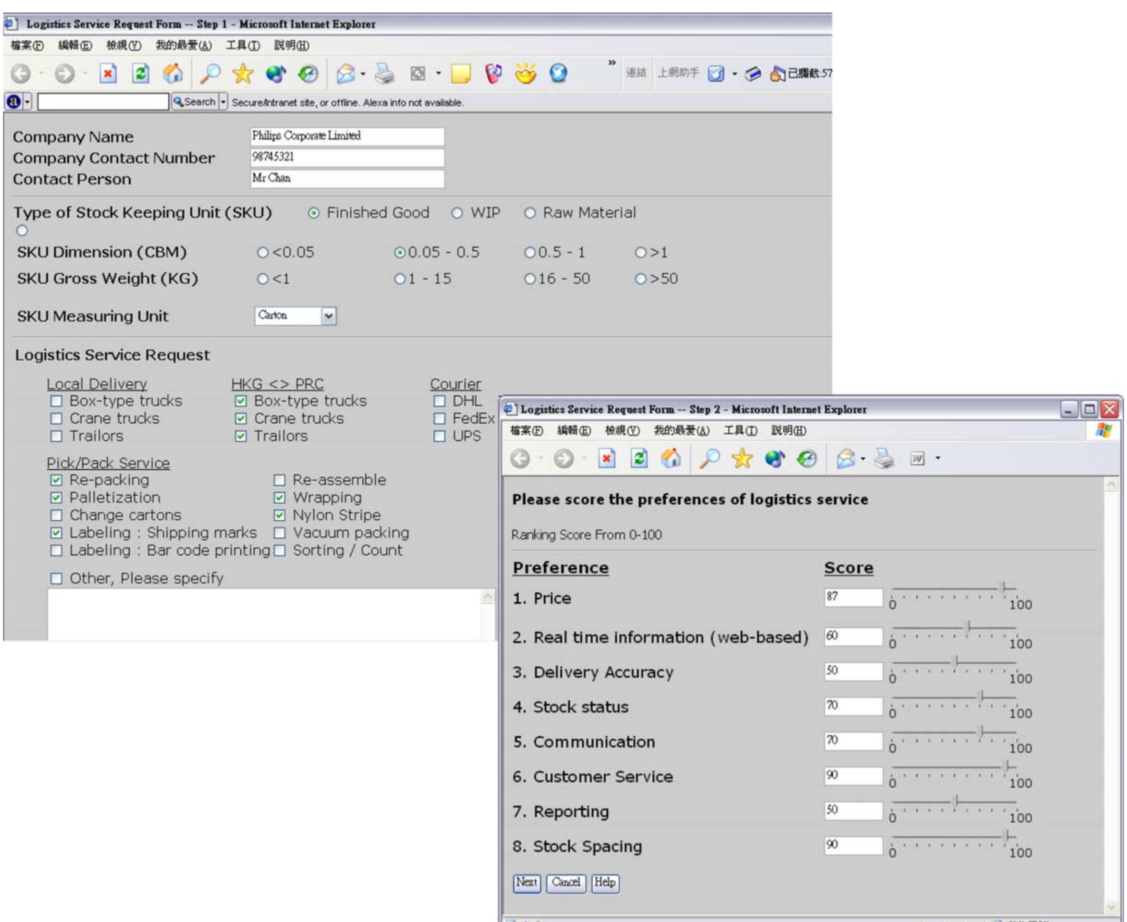

Fig. 7. The KLSS web-based platform.

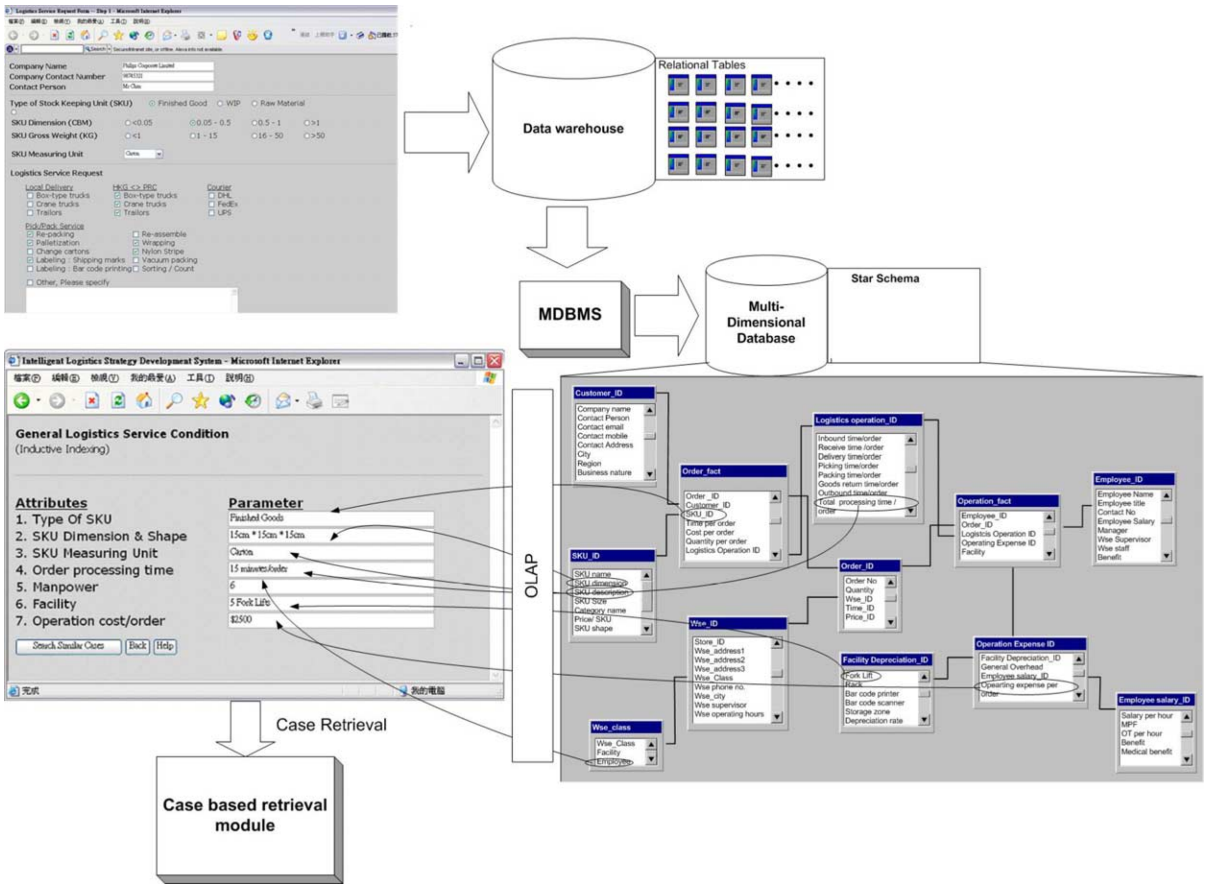

Fig. 8. Case attributes with corresponding parameters retrieved by OLAP for case retrieval process.

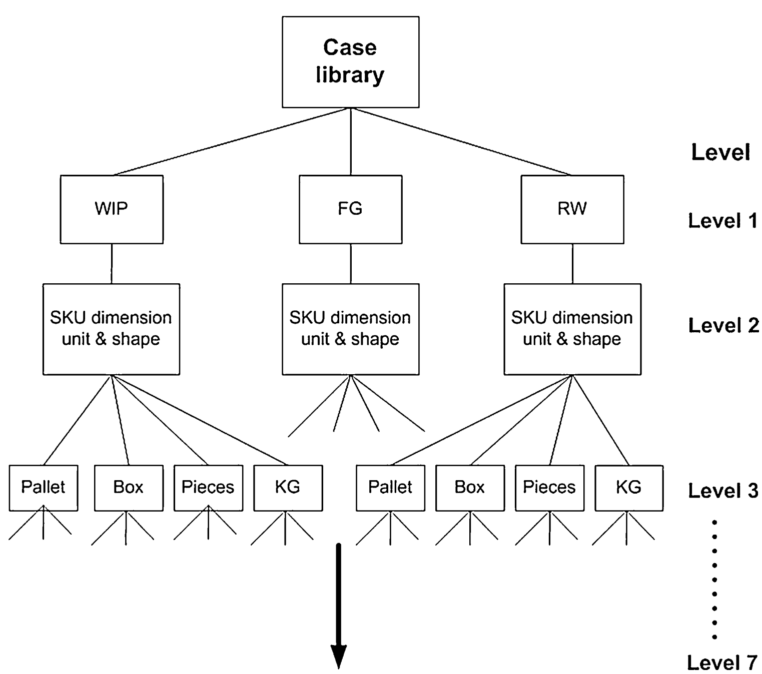

Fig. 9. Tree structure case library.

measuring units and various preference of logistics service are retrieved. After clicking the 'next' button, the screen of preference of logistics services is shown. A score for each preference is entered from '(1) Price' to '(8) Stock spacing'.

All the retrieved specifications and relevant logistics operating parameters are initially stored in the data warehouse in a relational table format. They are then transferred to the MDBMS module where all data is restructured into 3D data storage format as shown in Fig. 8. Such a data storage format facilitates OLAP application, which performs the drill down and roll up the database to extract a set of case attributes for case retrieval.

4.2. Step 2: Retrieve similar cases

The case retrieval process is performed by the retrieved engine utilizing inductive indexing approach and the nearest neighbor algorithm. In the beginning of the retrieval cycle, potential cases are retrieved by the inductive indexing approach. Types of specifications are first matched to identify a searching path, following the tree structure case library as shown in Fig. 9, where cases containing a set of indexed attributes are stored.

The case library has seven indexing levels:

Level 1: Type of SKU;
Level 2: SKU dimension and shape;
Level 3: SKU measuring unit;
Level 4: Order processing time;
Level 5: Manpower counting;
Level 6: Facility counting;
Level 7: Operating expense.

The case browsing of the case retrieval engine sub-module then generates a searching path across each indexing level in the tree structure case library as illustrated in Fig. 10. In doing so, a group of potential logistics strategy past cases is identified and retrieved by case retrieval sub module. In this case, five retrieved potential cases containing different similarity levels are retrieved following the nearest neighbor algorithm. Fig. 11 shows the case base of KLSS utilized in EWW.

4.3. Step 3: Rank similar cases

In this step, the similarity value of the retrieved cases is calculated by the nearest neighbor algorithm to rank cases in a descending order for selection purpose. As illustrated in

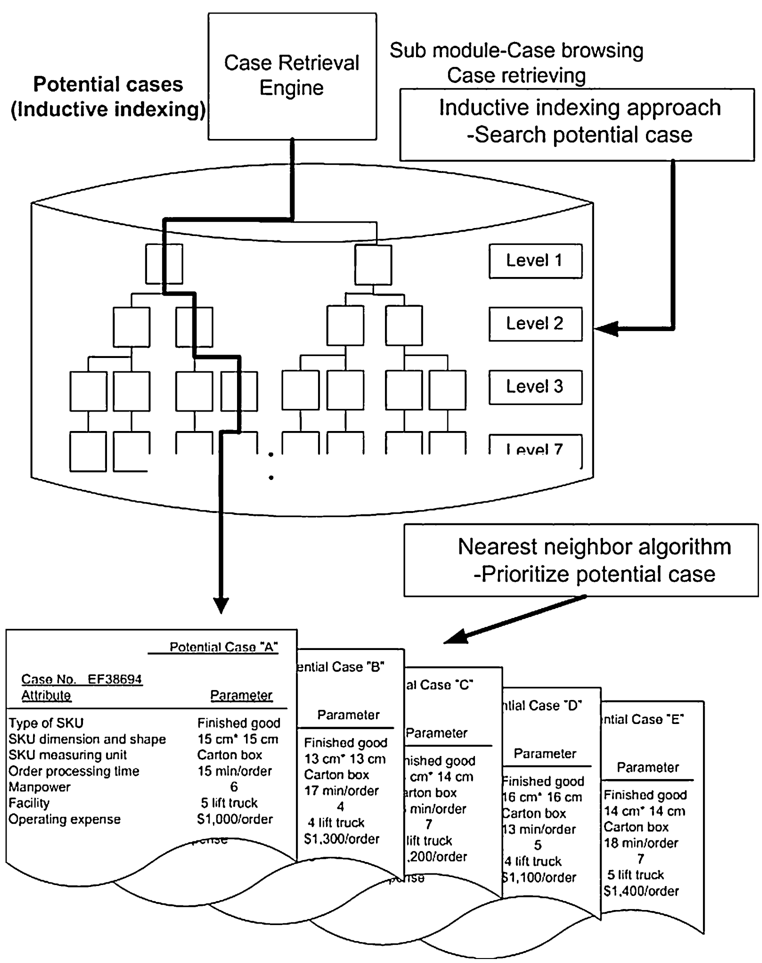

Fig. 10. The case retrieval engine.

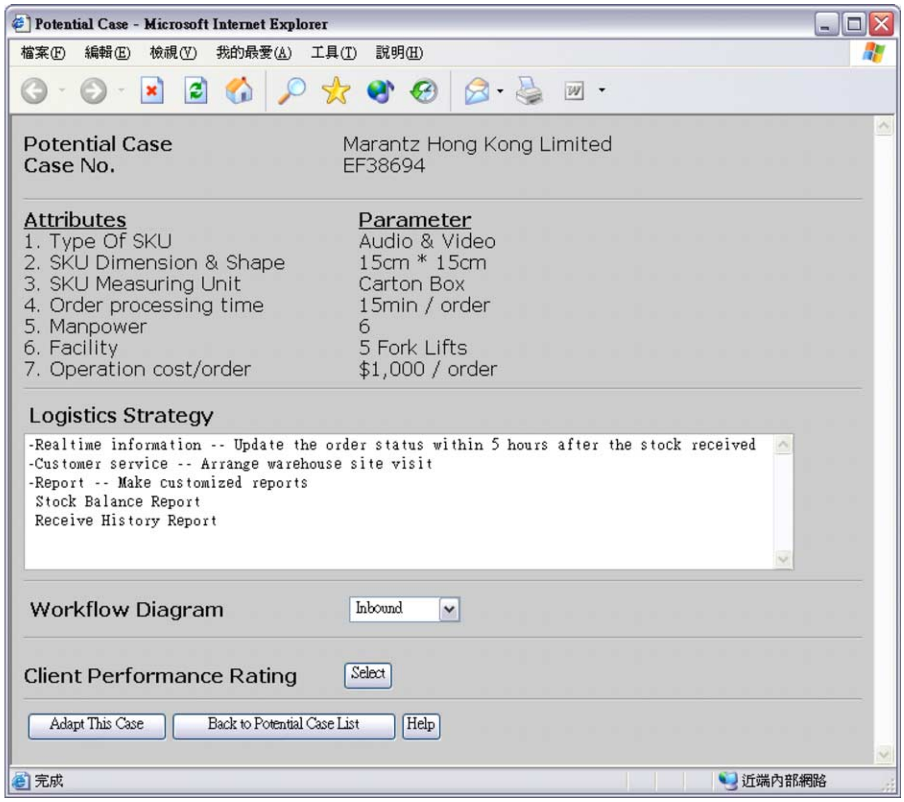

Fig. 11. A retrieved potential case.

Fig. 12, a potential case with case number EF38694 is taken for demonstrating case prioritizing. The first column is logistics service request. The second column is the weight assigned by current clients. The third and fourth columns are scores of current and potential case of the client's logistics service expectations. The last column is the similarity value of each pair of factors is calculated with the similarity calculation formula. By applying this formula, the similarity value of case with case 'EF38694' is 98.1%.

Fig. 13 shows that among five cases, case 'EF389694' has the highest similarity value which is the first choice in planning for a new logistics strategy.

4.4. Step 4: Accept the 'retrieved case'

This step decides whether adaptation should take place. Based on the result of Step 4, the strategy planner can either choose the case of the highest similarity value in Step 6 to create a logistics strategy or formulating a new one by using the case adaptation module.

4.5. Step 5: Revise similar cases

In this step, the case is revised to form an ideal logistics strategy by adopting a series of logistics strategy workflows and other logistics service planning issues like manpower resource allocation. The operating mechanism involves five stages as shown in Fig. 14.

4.5.1. Stage 1: Redesign the workflow

As shown in Fig. 15, a case of inbound workflow diagram is retrieved from the symbolic data format library. Based on the new client logistics service specifications, the retrieved workflow case is modified by filling in missing steps or removing unnecessary steps to fit the customers' logistics service requirements. Once the workflow is changed, relevant parameters like workforce and facilities are adjusted accordingly.

4.5.2. Stage 2: Resource allocation and operation efficiency prediction

In this stage, the new manpower and facility demand of modified logistics operation procedure is calculated by a strategy planner. Afterward, the operation efficiency of new operating procedures is predicted accordingly; the operating efficiency is an index for operators on performing the tasks. Lastly, the values of resource allocation and efficiency are recorded for calculating the new client's logistics operation expenses statement.

4.5.3. Stage 3: Performance rating recording

The preference of logistics services rated from Philips is retrieved from the data warehouse and automatically stored in the case library. The factors of logistics service preference rating are indexed for calculating similarity values.

Case Retrieval Engine

Sub module Case ranking

Case comparison process - Potential cases with case no. EF 38694 (Nearest neighbor)

Factor	Weightings	Input case (f^I)	Potential case (f^R)	Similarity value **(100 - $\lvert f^R - f^I \rvert$)/100 *100%**
1.Price	0.13	90	90	100%
2.Real time info	0.15	70	70	100%
3.Delivery accuracy	0.18	60	60	100%
4.Stock status	0.04	75	65	90%
5.Communication	0.18	75	75	100%
6.Customer service	0.19	90	90	100%
7.Report	0.06	50	30	80%
8.Stock Spacing	0.07	90	85	95%

Similarity value of the past case “EF38694”

= (0.13×100% + 0.15×100% + 0.18×100% + 0.04×90% + 0.18×100% + 0.19×100% + 0.06×80% + 0.07×95%)

=98.1%

Fig. 12. The case comparison process of the past case with Case no. EF38694.

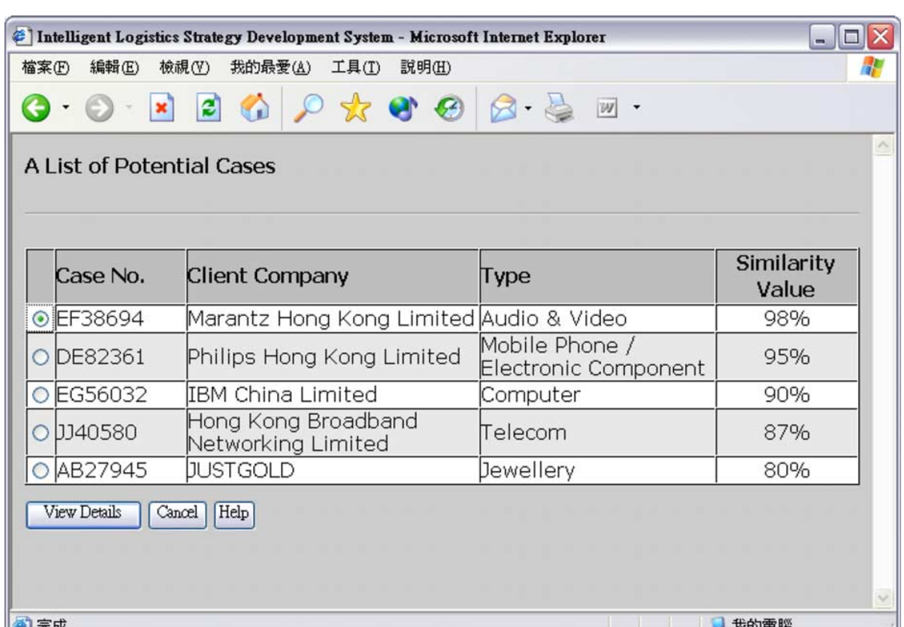

Fig. 13. A list of potential case.

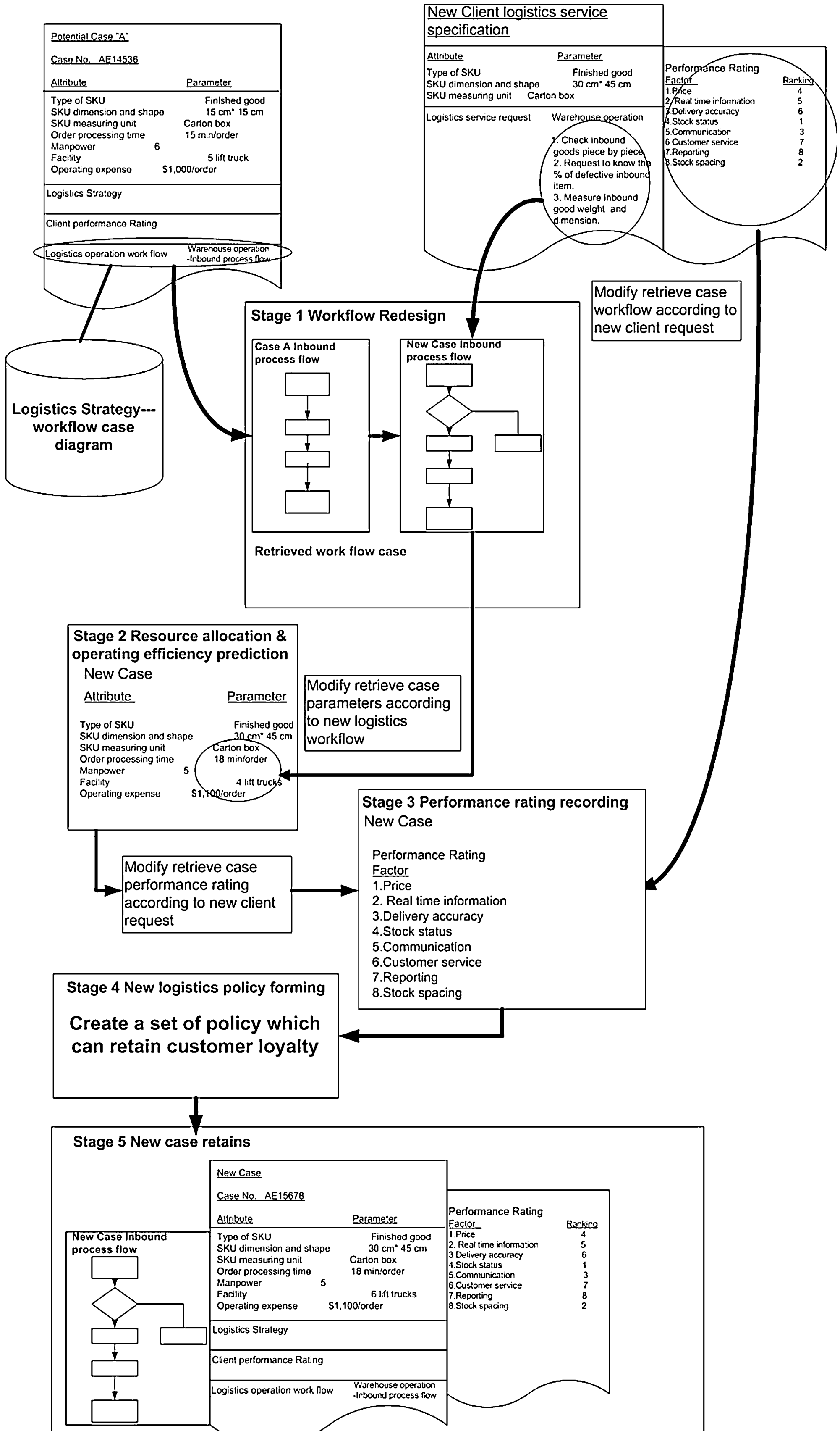

Fig. 14. The case adaptation stage in case adaptation module.

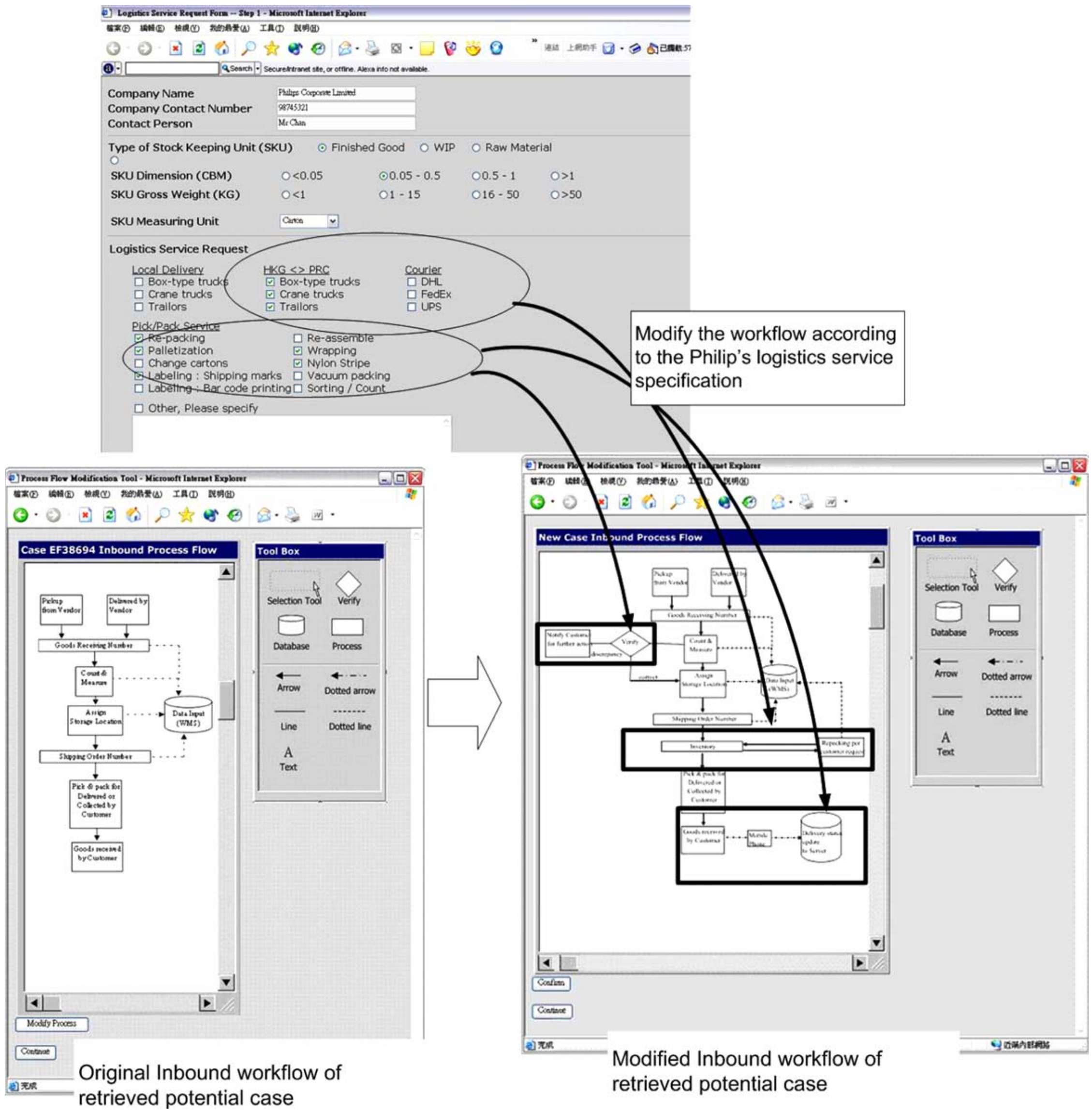

Fig. 15. Stage 1 workflow redesign to new case ‘Philip’.

4.5.4. Stage 4: New logistics operation policy formulation

A series of customized logistics operation policy is planned by modifying retrieved case logistics operation policy as shown in Fig. 16. For example, Philips ranks the stock status as the first preference. A series of logistics operation policy on keeping stock status with high visibility, such as updated information of stock status on web after each order transaction are then formulated in order to meet customer satisfaction.

4.5.5. Stage 5: Store new case

After the completion of new case adaptation, a new case is formed. A unique sequential case number is assigned to this new case. Thus, new case is saved in the case library for future reuse. Fig. 17 shows the new case of Philip.

4.5.6. Step 6: Retain new case

Once the new case is adapted, different data formats in the new case are stored in different case libraries. For example, symbolic data such as workflow diagrams is stored in the symbolic data case library. This new case will be adopted for future case forming.

5. Results and discussion

KLSS enhances the performance of logistics service providers at four different category levels. They are, namely: operation level, management level, customer service level and operation cost level. These levels and their relevant assessment factors are recorded and shown in Table 2.

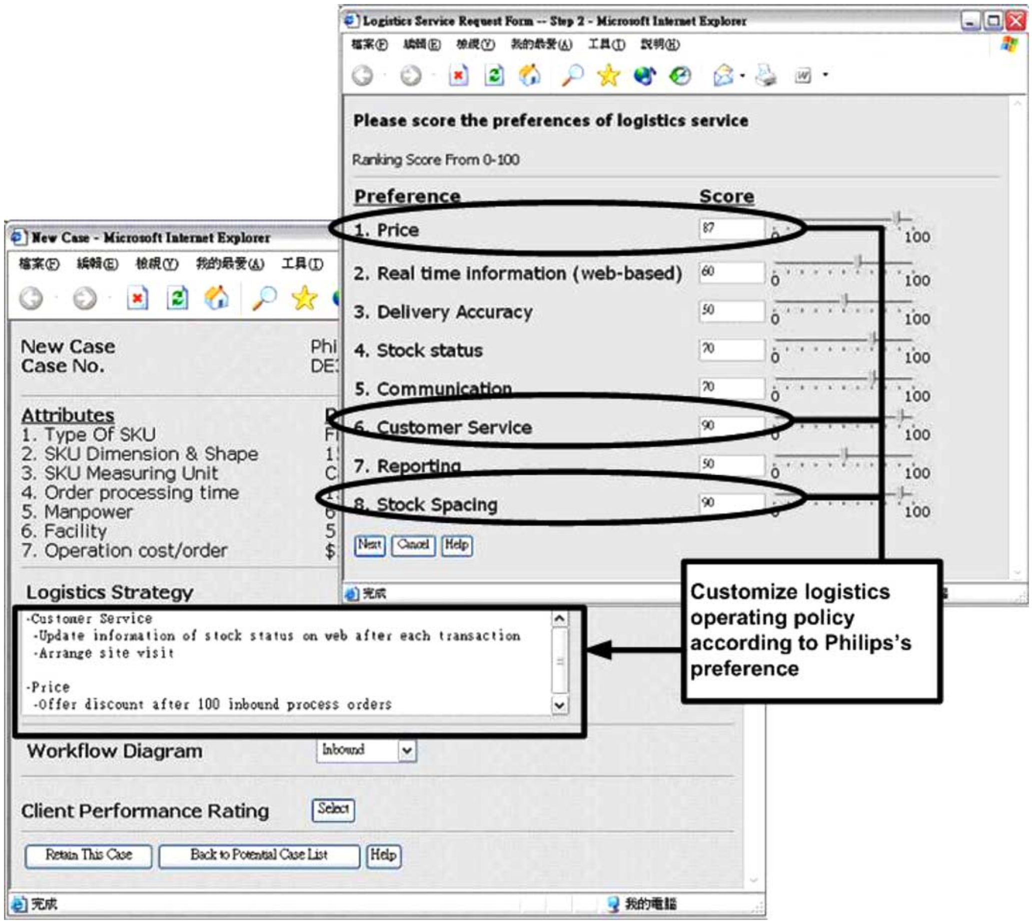

Fig. 16. New logistics operating policy formulation.

5.1. Improvement in efficiency

In the category of operation level, the efficiency of the inbound and outbound logistics process has improved by 33%, resulting from the development of streamlined line logistics workflow diagrams.

5.2. Reduction of operation costs

The operation costs in overtime, labor, and overhead cost per average order have declined by 30, 35 and 33%, respectively, indicating a saving of money by eliminating redundant activities.

5.3. Customer satisfaction enhancement

Customer claims due to late delivery and defective items have decreased by 80% showing that facilities scheduling like transport and other staff guidance has been planned and launched more efficiently.

5.4. Improvement of logistics planning time

Logistics strategy planning time in the category of management level has declined by 82% after KLSS implementation, revealing that accurate and useful information was offered in developing efficient logistic strategy.

In summary, all these results showed a greater improvement in EWW company performance due to the proper resource allocation and task analysis.

6. Conclusion

A good logistics strategy is important for logistics service providers to facilitate a company to succeed while minimizing current assets usage and maintaining high customer satisfaction level simultaneously. However, formulating good logistics strategy is always a challenge to logistics service providers. It is common that even experienced logistics planners always spend excessive time in seeking appropriate knowledge to formulate logistics strategies. This is mainly due to a lack of useful information or relevant knowledge support. In this paper, an intelligent system which incorporates CBR with data mining techniques to assist logistics service providers on logistics strategy development is introduced. Through integrating CBR and OLAP techniques in formulating logistics strategy, useful information and knowledge can be

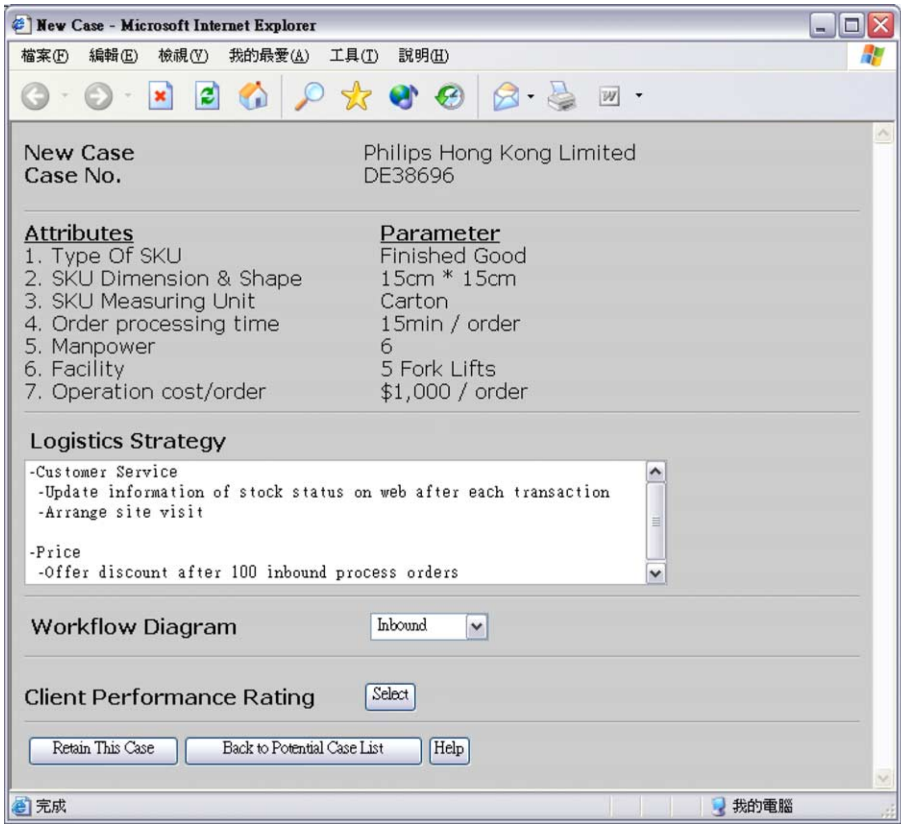

Fig. 17. New case of Philip.

retrieved at right time, thereby planning time is greatly reduced.

The capabilities and advantages of KLSS are demonstrated by implementing it in EWW Company. The KLSS operates by initially capturing raw data, discovering hidden data pattern and then transmitting into CBR engine to retrieve past similar cases with accurate and valuable knowledge for supporting logistics strategy planning. In addition, the hybrid CBR system is capable of self-learning capability. It learns from new stored case and reuses the experience gained in past cases. The continued improvement characteristics of CBR system can enhance the quality of logistics strategies.

In conclusion, by applying KLSS in logistics service companies, the goal of formulation of logistics strategies, which is enhancing competitive advantages through

Table 2
The assessment factors of four general categories

Category	Assessment factor	Measuring unit	Pre-implementation of KLSS	Post-implementation of KLSS	Percentage of improvement
Operation level	*Working efficiency*				
	Inbound process (unloading, receiving, shelving and stocktaking)	Minute/average order	45 min	30 min	33
	Outbound process (picking, packaging and shipping)	Minute/average order	60 min	40 min	33
Operation cost level	*Overtime cost*	Cost/20-heads/day	$4000	$2800	30
	Labor cost	Cost/20-heads/day	$10,000	$6500	35
	Overhead cost				
	(lift-fork, conveyors and IT equipment)	Depreciation cost/day	$1500	$1000	33
	Cost of electricity, fuel, repair, etc.	Cost/day	$2000	$2000	Nil
Customer service level	*Customer claim*				
	Delay in delivery	Order/month	10 orders	2 orders	80
	Defective items	Item/month	30 items	5 items	84
Management level	*Logistics strategy planning efficiency*	Cost/hour/logistics strategy plan	$2000/16 h	$375/3 h	82

utilizing resource and arranging work task efficiently as well as enhancing customer satisfaction, is achieved.

Acknowledgements

The authors wish to thank the Research Committee of the Hong Kong Polytechnic University for its support of the project. (Project code: 9051).

References

Aamodt, & Plaza, E. (1994). Case based reasoning: Foundational issues, methodological variations, and system approaches. *AI Com—Artificial Intelligent Communications*, *7*(1), 39–59.

Choy, K. L., Lee, W. B., Lau, Henry, Lu, Dawei, & Lo, V. (2004). Design of an intelligent supplier relationship management for new product development. *International Journal of Computer Integrated Manufacturing*, *17*(8), 692–715.

Choy, K. L., Lee, W. B., & Lo, V. (2003). Design of case based intelligent supplier relationship management system—the integration of supplier rating system and product code system. *Expert Systems with Applications*, *25*(1), 87–100.

Davenport, T. H., Jarvenpaa, S. L., & Beers, M. C. (1996). Improving knowledge work processes. *Sloan Management Review*, *37*(4), 53–55.

Dayal, U., & Chaudhuri, S. (1997). An overview of data warehousing and OLAP technology. *SIGMOD Record*, *26*(1), 65–74.

Fung, R. Y. K., & Ren, S. (1994). *A framework of decision support system (DSS) for agile enterprises rules, intelligent agents, STEP and workflow, architectures, networks, and intelligent system for manufacturing integration*. Pittsburgh, PA/Bellingham, WA: SPIE—The International Society for Optical Engineering (pp. 160–171).

Hokey, M. E., & Sean, B. (1994). An integrated decision support system for global logistics. *International Journal of Physical Distribution and Logistics Management*, *24*(1), 29–40. Bradford.

Humphries, M. (1999). *Data warehousing: Architecture and implementation*. Upper Saddle River, NJ: Prentice Hall.

Inmon, W. H. (1992). *Building the data warehouse*. QED Technical Publishing Group.

Jarke, M., & Vassiliou, Y. (2000). *Fundamental of data warehouses*. New York: Springer.

Kenan Technology (1995). *An introduction to multidimensional database technology*. http://www.Kenan.com/acumate/mddb_toc.htm

Kim, Y. G., Yu, S. H., & Lee, J. H. (2003). Knowledge strategy planning: Methodology and case. *Expert Systems with Applications*, *24*(3), 295–307.

Koegst, M., Schneider, J., Bergmann, R., & Vollrath, I. (1999). *IP retrieval by solving constraint satisfaction problems FDL'99. Second international forum on design language, ecole normale superieure de Lyon, Lyon, France, August 30–September 3*.

Kolodner, J. (1993). *Case-based reasoning*. San Mateo, CA: Morgan Kaufmann.

Liao, S. H. (2003). Knowledge management technologies and applications-literature review from 1995 to 2002. *Expert System with Applications*, *25*(2), 155–164.

Meade, L., & Sarkis, J. (2002). A conceptual model for selecting and evaluating third-party reverse logistics providers. *Supply Chain Management. An International Journal*, *7*(5), 283–295.

Srinivasa, R. P. (2001). Business intelligence and logistics. Wipro Technologies. *Source:* http://www.idii.com/wp/index3.htm

Stein, R., & Dahr, V. (1997). *Seven methods for transforming corporate data into business intelligence*. Englewood Cliffs, NJ: Prentice Hall.

Vannieuwenhuyse, L. G., & Pintelon, L. (2003). An online decision support system for transportation mode choice. *Logistics Information Management*, *16*(2), 125–133.

Watson, I. (1997). *Applying case-based reasoning: Techniques for enterprise systems*. San Mateo, CA: Morgan Kaufmann.

Watson, I., & Abullah, S. (1994). Developing case-based reasoning systems: A case study in diagnosing building defects. *Proceedings of the IEE colloquium on case-based reasoning: Prospects for applications, Digest No. 1994/057 1994 1/1–1/3*.

Wess, S., Althoff, K., & Derwand, G. (1993). Using *k–d* trees to improve retrieval step in case-based reasoning. In S. Wess, K. Althoff, & M. M. Richeter (Eds.), *Lecture notes in artificial intelligence 837, first European workshop, EWCBR-93 Kaiserslautern, Germany, November 1993*. Berlin: Springer.

Wiig, K. M. (1994). *Knowledge management. The central management focuses for intelligent-acting organization*. Arlington: Schema Press.

William, A. G. (2000). *Object oriented data warehouse design, building a star schema*. Upper Saddle River, NJ: Prentice Hall.