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EJB-MVC Oriented Supplier Selection System for Mass Customisation

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Abstract:

Purpose-This research is to develop a distributed system with an innovative supplier selection approach within a mass customization environment. It helps manufacturers to identify appropriate suppliers for the components, materials and services required within the procedure of product design and manufacture.

Design/methodology/approach- To identify the barriers for the supplier selection issues, current researches regarding the issues of supplier selection and mass customization have been reviewed. Based on the findings, the new supplier selection approach has been developed.

Findings: Within the global manufacturing environment, conventional way of appraising suppliers cannot enhance manufacturers' competitiveness advantage over their rivals. It is inevitable for manufacturers to identify appropriate competitive priorities for each of their potential market segments when designing products. Selecting appropriate suppliers is a fundamental issue to fulfill manufacturers' development strategy. The approach will enhance supplier selection efficiency and flexibility under the mass customization environment, enabling manufactures to avoid or minimize risks when external conditions change.

Research limitation/implications- The case study is limited to selecting suppliers of two components for an ink cartridge, however, the general approach is applicable to other type of products.

Practical implications: The whole concept of this selection system is to provide a supplier selection approach for mass customisation environment by utilising the Web-based technologies to deliver a means which enables geographically dispersed functions making supplier selection more efficiently. Manufacturers can utilise this approach to evaluate and to find most appropriate suppliers based on various situations.

Originality/value: The supplier selection approach focuses on the general supplier selection issues incorporating with product market position and development directions issues for mass customisation, which provides a more dynamic and robust method to select and evaluate potential suppliers according to a range of conditions.

Keywords: Mass customisation, Supplier Selection, Enterprise JavaBeans, Model-View-Controller, Analytic Hierarchy Process, Analytic Network Process

Article Type: Technical paper

Introduction

Customisation is one of the crucial factors for manufacturers to stay in a competitive position in today's turbulent environment(Pine, 1999; Davis, 1987; Frutos et al.,2004; Spring and Dalrymple, 2000; Brabazon and MacCarthy, 2004). In the current economic climate, where organisations pursue prime position in their industries, not only new products need to be developed fast and efficiently, but also the products need to be customised in a way to achieve competitive advantages. The mainstream of mass customization (MC) is focused upon flexibility and quick responsiveness through variety customized goods with low cost and high quality (Pine, 1999; Davis, 1987; Jiao et al, 2004). In view of the business process within the mass customization environment**,** customers, manufacturers and suppliers play major roles throughout the entire logistic chain (Coyle et al, 2002; Heizer and Render, 2001; Gattorna and Walters, 1996). As indicated by Christopher (1998), the scope of logistics spans the organization, from the management of raw materials to delivery of the final product, is directly related to the needs of customers. Many attentions have been paid to the customer satisfaction regarding mass customization (Frutos et al., 2004; Piller and Muller, 2004). However, the supplier involvement issue has not been specified as the customer involvement for MC. The benefits of integrating suppliers into customized manufacturing is well described in theory, but has not been well implemented in practice(Jiao et al, 2004). Many issues need to be concerned for the supplier involvement. This paper is particular focused on the supplier selection, because an appropriate supplier is an important factor for a manufacture to meet customers' requirements, which directly affect the way of a manufacturer to deliver products to a targeted market.

A Web-based supplier selection system has been previously developed by the authors (Hou and Su, 2004; 2006). Different from the traditional supplier selection method, the system provided a flexible way for manufacturers to find appropriate suppliers more efficiently when external environment changes. Twelve pre-defined initial matrices have been developed based on the survey results with AHP method, however, there are two major drawbacks to this system, the first is the supplier selection issue is only concerned within the general condition, and MC has not been particularly considered; the second is that the interactions among and between various factors have not been addressed properly for lack of dependence analysis in AHP. As mentioned before, increasing flexibility and quick responsiveness by providing sufficient variety of customized goods are the essential characteristics of MC, and furthermore, the competitive market place and continual pressure on product improvement push manufacturers to alter their relationship with suppliers. As a result, it is necessary to modify supplier selection criteria in order to meet the requirements under the MC environment.

The purpose of this research is to establish a Web-enabled, in particular, Enterprise JavaBeans (EJB) and Model-View-Controller(MVC) oriented system with a novel supplier selection approach for MC to help manufacturers to identify suitable suppliers for the components, materials and services required within the process of product design and manufacture. The state of the art Web-based technologies, the business models and the Analytic Hierarchy Process (AHP)/Analytic Network Process(ANP) decision making methods are integrated to implement the system.

Literature Review

Theoretical Basis for the Supplier Selection Method for Mass Customisation

Customisation through the standardisation of components not only increases product variety while reducing costs in manufacturing, but it allows product development to produce new designes and proliferate even greater product variety much more quickly. MC was denominated by Davis (1999), intending manufacture products that are individually tailored taking advantages of the cost benefits that a traditional mass production offers. Since then, the concept of mass customization became the most popular theme where the attentions dramatically spread. Five fundamental methods for effectively achieving MC are presented by Pine (1999), including customize services around standardized products and services, create customizable products and services, provide point of delivery customsiation, provide quick response through the value chain, and modularize components to customize end products and services. Each of them has own particular means to reach MC, and the method of *Modularize components to customize end products* has been credited as the best for achieving MC from manufacturing's perspective. Six types of modularity are contained in this method, including component-sharing modularity, component-swapping modularity, cut-to-fit modularity, mix modularity, bus modularity and sectional modularity. Traditionally, potential suppliers are evaluated against several criteria such as technical capability, material selection, production technology, costs, product quality, service and geographical location (Coyle et al., 2002; Gattorna and Walters, 1996). However, under the influence of the global turbulence environment, the conventional way of appraising suppliers cannot give manufacturers a competitive advantage over their rivals (Heizer and Render, 2001). It is inevitable for manufacturers to identify appropriate competitive priorities for each of their potential market segments when designing products (Su et.al., 2003). Selecting appropriate suppliers is fundamental for fulfilling manufacturers' development strategy.

With consideration of the inherency of the MC, products can be classified into four types: unique customised product with premium price, customised product with standard fit, less customised product with lower price, and hybrid product with reinvestment in low price and differentiation. These types of products can be pursued as development directions for a manufacturer to implement its competitive strategy. In pursuing these competitive advantages, a manufacturer has to make decision, whether it will target at a particular market segmentation or go for a broad market. These choices define four basic approaches to competitive advantages illustrated in Ansoff's alternative directions for strategy development (Ansoff, 1987; 1998), including protect position, product development position, market development position, and diversification position. According to different market positions and development directions, manufacturers can position themselves in a number of ways within the industry; as a consequence, the requirements for selecting suppliers differ from one to another. With regard to these factors, tangible criteria inevitably need to be counted, such as pricing structure, delivery capability, product quality, technology capability, service issues, etc. In addition, intangible factors also need to be taken into account, such as influences by internal issues, for instance, strength, weakness, opportunity and threat(SWOT); and external changes, such as political, economical, social and technology(PEST)(Johnson and Scholes, 1999).

The approach developed by this research is based on the six types of modularity, combining the product market development strategy with product market development positions to deliver a novel supplier selection method for mass customization. The six types of modularity can be implemented for each type of products with different product development strategies, which depend on the manufacturers' product development market positions. The method will enhance supplier selection efficiency and flexibility under the MC, enabling manufactures to avoid or minimize risks when external conditions change. Figure1 shows the coalition of the product development strategies with product market positions under the six types of modularity.
TAKE IN FIGURE 1

Multi-Decision Making Methods: Analytic Hierarchy Process (AHP)/Analytic Network Process(ANP)
The AHP/ANP are developed by (Satty, 2004). The AHP/ANP methods use paired comparisons to represent judgments and highlights the role of inconsistency in the decision making process. The methods are based on a multicriteria measurement theory which provides a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower level elements (Satty, 2004). In addition to AHP/ANP, several multi-criteria decision making(MCDM) methods exist(Anderson, 2003; Curwin and Slark, 2002; Fishburn, 1996; Miller, 1969; Bowen, 1990), such as Weighted Sum Model (WSM), Weighted Product Model (WPM), ELECTRE Method, TOPSIS Method, etc. The comparisons between AHP/ANP and the other MCDM methods are carried out among researchers (Triantaphyllou, 2002; Bhutta and Huq, 2002), which revealed that AHP/ANP possess a number of benefits over other methods, such as providing a realistic description of the problem, supporting group decision-making, structuring the decision-making process, incorporating both quantitative and qualitative factors, expressing the relative importance of factors, allowing the decision makers to focus on each small part of the problem, analysing alternatives, etc.

The supplier selection approach presented in this paper is derived from the business strategies in combination with the AHP/ANP decision-making methods, which provides a more dynamic and robust means to select and to evaluate potential suppliers according to a range of conditions.

System Architecture and Implementation

The main features of this system that differs from the existing supplier selection systems are: (1) ability to effectively take MC related business strategies and product market positions into consideration, (2) accurate and reliable comparison and assessment of suppliers based on the AHP/ANP methods, and (3) providing a distributed environment with the features of scalability, heterogeneity, modular decomposability, modifiability, and reusability.

Information sharing and communication are essential to support this supplier selection system. Due to concurrency, consistency, reliability and security issues, it is crucial to apply appropriate Web oriented technologies for the system implementation.

Enterprise JavaBeans (EJB) and Model-View-Controller(MVC) design pattern haven been integrated to implement the system. EJB is the latest technology abstraction in Java Family(JavaSun, 2005; IBM 2003), which provides an abstraction for component transaction monitors. EJB provides a standard distributed component model that greatly simplifies the development process and enables that beans are developed and deployed on one EJB server to be easily deployed on a different EJB server. MVC is the design pattern which organizes an interactive application into three separate modules: one for the application model with its data representation and business logic, the second for displaying the data or information of an application, and the third coordinates the former two in order to display the correct interface or execute works to implement the application needs to complete. The primary advantages of integrating EJB and MVC pattern is to separate design concerns, decrease code duplication, centralize control, and make the application more modifiable.

The system contains two major parts: Data Bank and Evaluation Matrices. The mainstream of the Data Bank is for users who possess privileges of authentication and authorization to efficiently extract suppliers' information in various situations; while the purpose of the Evaluation Matrices is to provide various patterns that integrated business schemes with the AHP/ANP methods for people who are involved in the total design process to select suppliers efficiently. Within this EJB-MVC oriented system, only the user interface stays on local machines while the logic of the application runs in the middle tier on a server, and the database tier is managed by an Enterprise Information System. The main advantages of using this MVC structure is to satisfy demands when the number of requestors increases, the logic can be updated easily in one place on the middle tier without having to load new logic on every client's machine, meanwhile the data provided by this structure is 'hidden' away from other components. The method of accessing data and its preparation can be transparently changed without affecting the rest of the application. When the logic of an application need to be updated, changes are made to the software of the middle tier on the server, greatly simplifying the management of the updates.
TAKE IN FIGURE 2

Figure 2 shows the architecture and functionality of the supplier selection system. The Model panel represents the business state and business activities of the system, in particular, EJB based Data Bank and Evaluation Matrices, and as such it is decoupled from the View and Controller panels. The View and Controller panels interpret the resources and logic provided by the Model panel, however, these panels completely unaware of how the data were retrieved. In this implementation, a set of Servlets is used as Controllers, the JSP is utilized as a View, and the EJB plays a role as a Model. The Data Bank and Evaluation Matrices are completely unconcerned with presentation of the results in the View; it merely responds to events triggered by the Controller. Within the Data Bank, the users can search and investigate suppliers' information based on different conditions. The requirements can be presented in the View panel to capture suppliers' rating weights, various conditions and so on. The Data Controller and Evaluation Controller can access to the Model panel through the EJBs that represent. The security, scalability, heterogeneity, and reusability are major concerns for this supplier selection system, and it is sensible to hide as many techniques as possible within the infrastructure to avoid users directly access certain functions which may reduce security and consistent usage. Hence, the details of the Data Bank and the Evaluation Matrices are not exposed to users until users' identities have been identified, only users in assigned roles can access certain methods in the Enterprise Beans.

Data Bank

As illustrated in Figure 2, the Data Bank has two major sections, namely, Finder and Refined Filter. The two sections are logically constructed, and can represent themselves independently or jointly. The Stateful Session bean and Entity bean are applied in the Data Bank. The Stateful session bean can be used for an individual who visits the system on the Web. The beans can maintain the client's state, which means they can retain information for the client. Due to short life cycle of Session beans, the bean is removed by the client when the client ends the session. Unlike Session beans, Entity beans are considered to be long-lived. The vital advantages of using Entity beans are the simplicity of the task of accessing and manipulating. It can be automatically reset to the state of the last committed transaction, which avoids the data loss when system crashes during the deployment.

Finder Section The section is designed as entity beans. Suppliers' information is stored in terms of the tangible criteria. The system gathers user's requirements on a particular category by specifying the value in that category in order for the record to be returned to the user. For example, if the user seeks information concerning the quality issues, and all potential suppliers' detail information related to the quality will be displayed, the user will be able to made decision either fetches suppliers' weights from the Refined filters or visits Evaluation matrices in order to compute suppliers' rating weights based on the different conditions.

Refined Filter section This section is designed as Session beans, which consists of three filters: the product strategy-based filter, the product market position based filter, and the six types of modularity based filter. The data in this section is based on the original information, which contains information provided by suppliers and categorized by the system, and the suppliers' final rating weights extracted from the Evaluation matrices. For example, if the users intend to develop their product under one type of modularity, they will get two types of information: one is the classified original suppliers' information, such as quality, service, cost, location and technology capability, etc; the other is the suppliers' rating weights received from the Evaluation matrices for the different types of modularity. The functionality of this section is for users to choose relevant supplier's information according to their product development strategies, product market positions and the six types of modularity. Under the Modularity-based filter, the information is arranged by six types of modularity with four potential product market positions and four types of strategies, for example, if users pursue their new product in a new market (NPNM) with the Unique focus strategy for cut-to-fix modularity, and they can achieve a result that different from the new product in an existing market(NPEM) under the same condition. The similar functionality is applied to both the Product market position-based filter and the Strategies-based filter.

Evaluation Matrices

The Evaluation Matrices are derived from the business strategies in combination with the AHP/ANP methods, which provide a more dynamic and robust means to select and evaluate potential suppliers according to a range of conditions. Three types of Evaluation matrices are contained in the Evaluation Matrices, including Modularity based matrices, Product Market Position based matrices, and Product Strategy based matrices. The matrices are logically dependant and independent to each other. Depending on the intention of manufacturers, the users are free to apply any individual type of matrix when selecting potential suppliers. The suppliers' rating weights from the different types of matrices can be interlinked to help users select the best-fit suppliers. Due to the complexity of the AHP/ANP methods within the MC conditions, it is necessary to explain the structure for the three types of Evaluation matrices. However, considering the limitation of the paper length, the authors chose the Modularity based matrices for illustration purpose. The detailed working procedure with an example can be found in case study section.

Many factors need to be taken into account when applying MC into various situations. Due to the particularity of each situation, it is important to be aware of the requirements for each MC conditions before applying the approach. The component sharing modularity is taken to illustrate the structure of this supplier selection approach. The primary advantages of applying component-sharing modularity is to greatly reduce costs while providing more variety and speedier product development. To develop comprehensive comparisons for supplier selection, a number of issues that have been mentioned in the literature review are integrated to implement the evaluation process.

TAKE IN FIGURE 3

The structure of the selection model is described by its clusters and elements, and by the connection between them. In the Top of Figure 3, the goal is to select suppliers within the customization conditions; strategy cluster and position cluster are included in the network. As shown in Figure 3, under the condition of component-sharing modularity, four types of positions and strategies are separately contained in the strategy and position clusters which interact with each other that are known as outer dependence; the elements within the position and strategy clusters are depended on each other resulting in dependence are known as inner dependence. The PEST(Political, Economical, Social, and Technology) and SWOT(Strength, Weakness, Opportunity, and Threat) issues as intangible sub-criteria are composed in the position cluster, while the tangible criteria are included in the Strategy cluster. Five steps are needed to complete the supplier selection process, the working procedure is briefed shown in the following section.

A Case Study

Background

CompanyY is a subsidiary of a Chinese domestic manufacturer of printers. The manufacturer produces own-brand printer consumables for both local and overseas markets. CompanyY is responsible for manufacturing ink cartridges; the products are designed for a wide range of printers. According to the market research, despite the large number of ink cartridges sold each year, consumers have complained about the high cost of ink cartridges and looked for alternatives. There are three types of ink cartridges available in the market, including original equipment manufacturer ink cartridges that are manufactured by the same printer manufacturer, compatible ink cartridges that are manufactured by a company other than the original printer manufacturer, and remanufactured ink cartridges that have been refilled with ink. The competition in the industry is intensive. Two major challenges which need to be addressed for the companyY: the first one is derived from distinguished international competitors, such as HP, EPSON, Lexmak, etc, who have built splendid reputation for printers and associated consumable products; the second one is from 3rd party ink manufacturers who often keep update with compatible cartridges. Compared to its rivals, CompanyY has remained as a fair player in the industry. To keep the existing market position and to expand potential markets, CompanyY needs to reconstruct its development directions in order to win a competitive position. For the future development, the company plans to utilize the same components for the products that across multiple categories to provide economies of scope. As the most important components for a printer, ink cartridges possess considerable potentials for supporting various standards printers for different market segmentations. According to the nature of the industry, the potential for the company remains its position is to create modular components that can be configured into a wide variety of products. CompanyY decided to adopt the MC modularity method for future product development. The majority components, which are provided by the existing suppliers, can still be satisfied for the requirements. However, some components need to be altered to fit the intention within MC. The company decided to evaluate suppliers in different categories based on the different types of modularity. In general, there are 16 components are contained in a ink cartridges, some of which are produced within the company, others mainly depend on external resources. Considering that, it would not be possible to illustrate all the selection processes for each of the components with each of the conditions in this paper, ‘air valve coil spring’ and ‘centre coil spring’, are taken as examples to illustrate

the procedure of selecting suppliers. The specifications are shown in Table 1.
TAKE IN TABLE 1

Utilization of the system

As mentioned earlier, most of components can still meet the requirements for MC condition, hence, it is imperative for CompanyY's team members to find the related information from the Data Bank first before using the Evaluate Matrices to evaluate suppliers for the reset of components. The first thing the UserController to do is to check the users' identity in order to point them into a right section. Users at different levels have different ownerships for some certain information access. The information stored in one section is not available with same accessibility level to all users. Within the system, a user can access both front-end Web application and back-end resources based on his/her role membership. The roles are used as logical containers that group users who share the same information and the role membership is used to control the access to specific operations exposed by the information. There will be three levels of privilege available, including individual level, group level, and cross function level. The roles are stored in the MYSQL database. The system will automatically distinguish users and send back the corresponding Web page to them. Afterwards, it checks the users' requirements and uses these facts to query the Data Bank to retrieve a set of relevant suppliers' information. The results stored in the server's database are accessible for certain users at any time through the Web browser. At this point, the Servlets can update information by invoking methods on the remote object. The Controllers can transfer control to an appropriate View pages to assemble the results into presentation format and route results back to the users. If the users have not found the results from the Data Bank, the requests will reach to the Evaluation Matrices and the users will able to compute, compare and select their favorites suppliers according to various requirements. The case study illustrated here supposing that the most of related suppliers' information have already found by following procedures from the Data Bank;the users need to find suppliers who can provide the components that meet the specifications. Based on the information submitted by suppliers who have already reached components specifications, three of them have been selected for the evaluation. Evaluation Matrices are utilized for evaluating potential suppliers.

It is essential for users within the same project team to collaborate with each other in order to obtain more reliable and updated information. Each step within the supplier selection procedure is encapsulated with Enterprise JavaBeans. Stateless and Stateful session beans are applied in the Evaluation Matrices. Each authorized user possesses individual temporary and personal storages, respectively. The Stateless session beans work on any temporary storage and hold no client-specific state. After a valid user logs into the system, a new storage will be created. Because the user may leave this system without any appropriate supplier's information, so the storage needs to be client-specific state without persistence. Unlike the stateless session beans, the stateful session beans enable users to manipulate suppliers' information from their personal storage as the users visit Evaluation Matrices. Each stateful session beans holds conversational state about the user's current storage, for instance, when a user make the paried comparison based on information gained from the three suppliers, the results will be hold as one independent object. The Stateful session bean is not a persistent object until it has been converted into the Data Bank. In this case, the users could theoretically stop a visiting session and later return to the Evaluation Matrices and still access to the same information. The bean must be associated with a particular user which can maintain the list of information the user selected. It takes a paired comparison matrix as input and calculates potential suppliers' raking weights based on a particular Matrix that the user required. Once the raking weights have been computed, and it is available to perform another computation. The suppliers' final results can be obtained based on the comparison ratings that are given by each individual team member. All the procedures above are happened within the EJB-MVC environment. Due to the functionalities of the system have already been introduced previously, the following are concentrated on illustrating the supplier selection approach for MC environment. Five steps are needed to complete the process; the working procedure is briefed below.

Structure of AHP/ANP based supplier selection

<u>Paired comparisons</u>

The first step of the process is to make paired comparisons. The pair-wise comparisons using the fundamental of Satty's scale[16] for the comparative judgment. Paired comparisons are required for all the connection for the selection approach. Two types of paired comparison are included in this step: one is the clusters comparison that contains eight separate matrices for position cluster and strategy cluster, respectively; the other is the elements comparison matrices, where are in total of eight matrices for the elements in both position and strategy clusters. For the cluster paired comparison, the relative importance of each product market position with respect to a particular strategy and the relative importance of each kind of strategy with respect to a particular product market position are needed to express the bi-directional relationship. It is not possible to display all the comparison are involved for this selection, the Tables are shown in the following are chosen from each type of comparison to illustrate the various comparison for this selection procedure. Table 2 shows paired comparison for product market positions under the Speed strategy, the same type of comparisons will be applied to all the types of strategies cluster as well as product market positions cluster. The same principle is also applied to the element comparisons. Table 3 shows paired judgments of the PEST and SWOT criteria under position cluster for EPEM, while Table 4 shows paired judgments of the tangible criteria under strategy cluster for Speed strategy. The weights are obtained from the users by asking a series of comparison questions, such as how much more important is Political issue than Economical issue if new product is explored in a new market(NPNM). Table 5 shows the derived priority weights from the judgments obtained from the comparisons of the PEST and SWOT criteria under product market positions cluster, the relative importance ratings for NPNM condition are shown in italic numbers in Table 5. The results shown in italic in Table 6 is derived from Table 4. The priorities, which are derived from paired comparisons, will be used for calculating the weighted supermatrix.

TAKE IN TABLE 2

TAKE IN TABLE 3

TAKE IN TABLE 4

TAKE IN TABLE 5

TAKE IN TABLE 6

The supermatrix

A supermatrix is a two-dimensional matrix of elements by elements. In the development for this supplier selection model, the interdependence happened between position and strategy clusters which are shown as priorities that are derived from eight pariwise comparison in Table 7. The final priorities for the Position-Strategy matrices will be obtained from the limiting power of this matrix.

TAKE IN TABLE 7

Limiting supermatrix

The reason for calculating the limiting supermatrix is because the interaction in the supermatrix is measured based on the different criteria, which resulting the stochastic matrix; it is crucial to compare clusters in terms of their impact on each other with respect to the general criterion for several times in order to transform it to a stochastic matrix. To get relative importance weights for evaluation purposes, a markowian-based analysis is completed to achieve a convergent set of weights. According to markowian analysis, raising the matrix to powers gives the limiting matrix that represents all possible interactions in the system. The convergence is happened 128th power in this example.

TAKE IN TABLE 8

Weight supermatrix

It is imperative to connect the elements with the clusters to which they belong, to determine their relative overall weight among all the elements in the other clusters. An eigenvector can be yielded for the influence of all the clusters on each other. Table 9 and Table 10 show the priorities of the elements of eigenvector are used to weight all the elements in the block of the Table 8 that correspond to the elements of both the influencing and the influenced clusters in Table 5 and Table 6. The symbol of CSP is shown in Table 9 expresses the priorities of the product market position elements to the overall objective; the symbol of CSS is shown in Table 10 expresses the priorities of the strategies elements to the overall objective;

TAKE IN TABLE 9

TAKE IN TABLE 10

Suppliers Comparison

Potential suppliers who are in the selection short list need to be evaluated based on the results achieved from above mentioned stages. For this supplier selection model, the relative importance of the supplier selection factors depend upon the types of CM, the requirements for various clusters and their attributes will differ from different CM conditions. For example, for the component-sharing modularity, the requirements for selecting suppliers would not be the same as the component-sweeping modularity. The matrices are logically dependant and independent to each other. The suppliers' weights from the six types of matrices can be interlinked to help decision makers select the best-fit suppliers. Depending on the future development directions, manufacturers can utilize the model to distinguish their suppliers according to their future directions.

Suppliers comparison

To evaluate suppliers for the component sharping modularity, the equation is defined as follows:

$$Di=\Sigma CSP(CSS)\ SS$$

Where,

Di is the desirability index for all the suppliers;

CSP is the priorities of the position elements to the overall objective;

CSS is the priorities of the strategy elements to the overall objective;

SS is the relative importance weight for suppliers for a particular measurement.

There are three suppliers in the selection short list which are evaluated based on the results achieved from above steps. Due to the limitation of the paper length, it is difficult to display all the results for each single elements, the final results are given in Table 11:

TAKE IN TABLE 11

The final results show that Supplier 1 has the highest scores under the component sharing modularity. As aforementioned, the ANP approach consists of clusters and elements that connected by their dependence to one another. A cluster therefore allows one to think about grouping elements that share a set of attributes. For this supplier selection model, the relative importance of the supplier selection factors depend upon the types of MC, the requirements for various clusters and their attributes will differ from different MC conditions. For example, if CompanyY pursues the product with component-sweeping modularity, the requirements for selecting suppliers would not be the same as the component-sharing modularity. Depending on the future development directions, CompanyY can utilize the model to distinguish their suppliers according to their future directions.

Conclusions:

Mass customisation is a means for manufacturers to remain a competitive position in today's turbulent environment. Extensive literature review reveals that under the mass customization conditions, the selection of suppliers not only is a technical decision, but also needs to consider factors from external and internal influences. Strategy is a major concern for manufactures to meet the needs of markets within the global changing environment. Once a strategy is in place, the specific task of deciding how to undertake the low cost production of individually customized products remains. An EJB-MVC driven supplier selection system has been developed. The system utilizes state of the art Web oriented technologies as tool to deliver a novel supplier selection method that integrates leading business theories with AHP/ANP approaches for mass customisation.

The purpose of the Web-enabled system is to help manufacturers to identify suitable suppliers for the components, materials and services required within the procedure of product design and manufacture, and to be able to fast shift their supplier selection directions in order to adapt external environment changes. Integrating EJB technology and MVC pattern dramatically improve the performances of the supplier selection system. The superior advantages for combining EJB with MVC architecture are to separate design concerns, decrease code duplication, centralize control, and make the application more easily modifiable. The example provided has demonstrated that utilizing the new developed supplier selection approach effectively aids manufacturers to find a suitable supplier in a MC situation.

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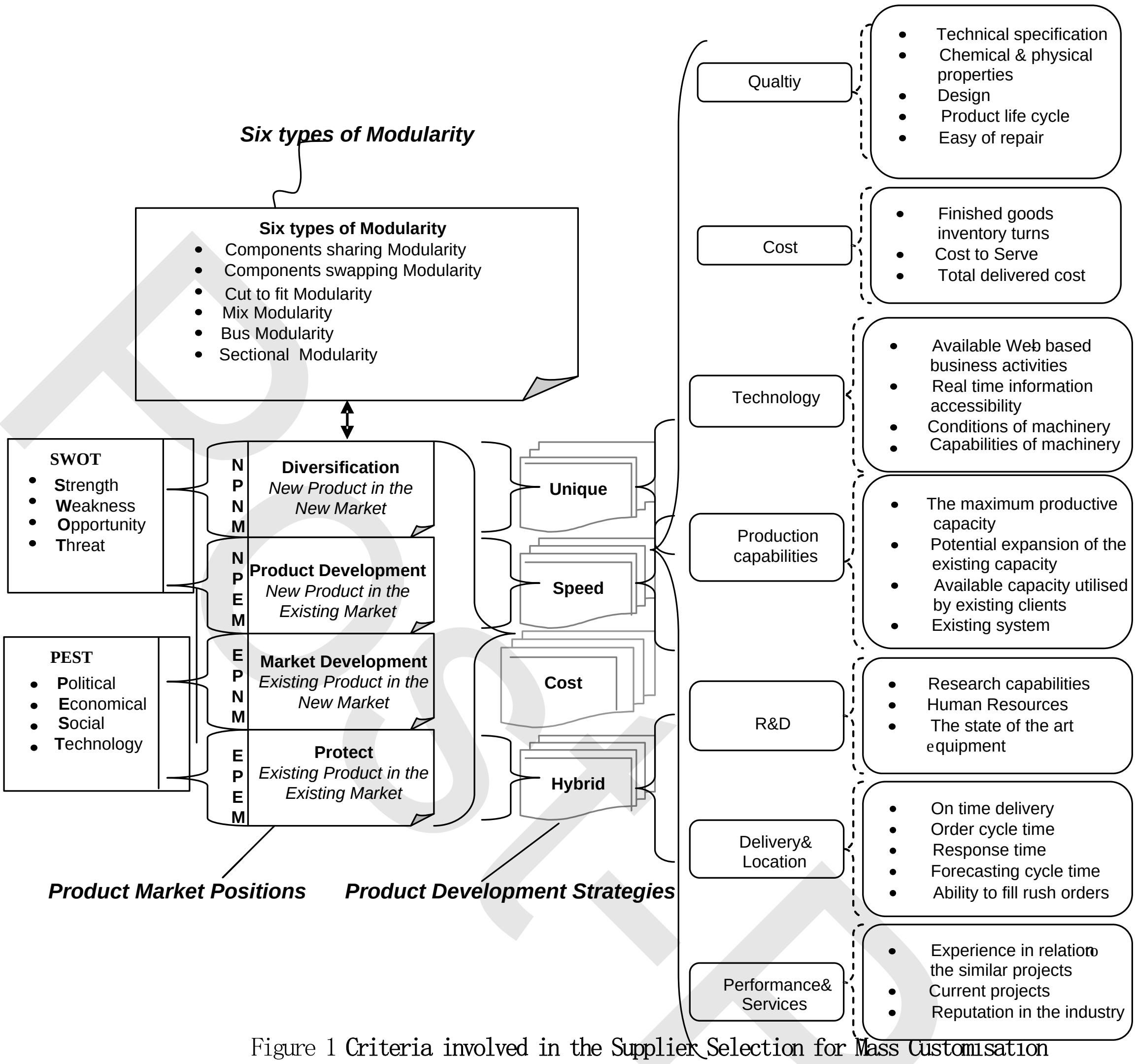

Figure 1 Criteria involved in the Supplier Selection for Mass Customisation

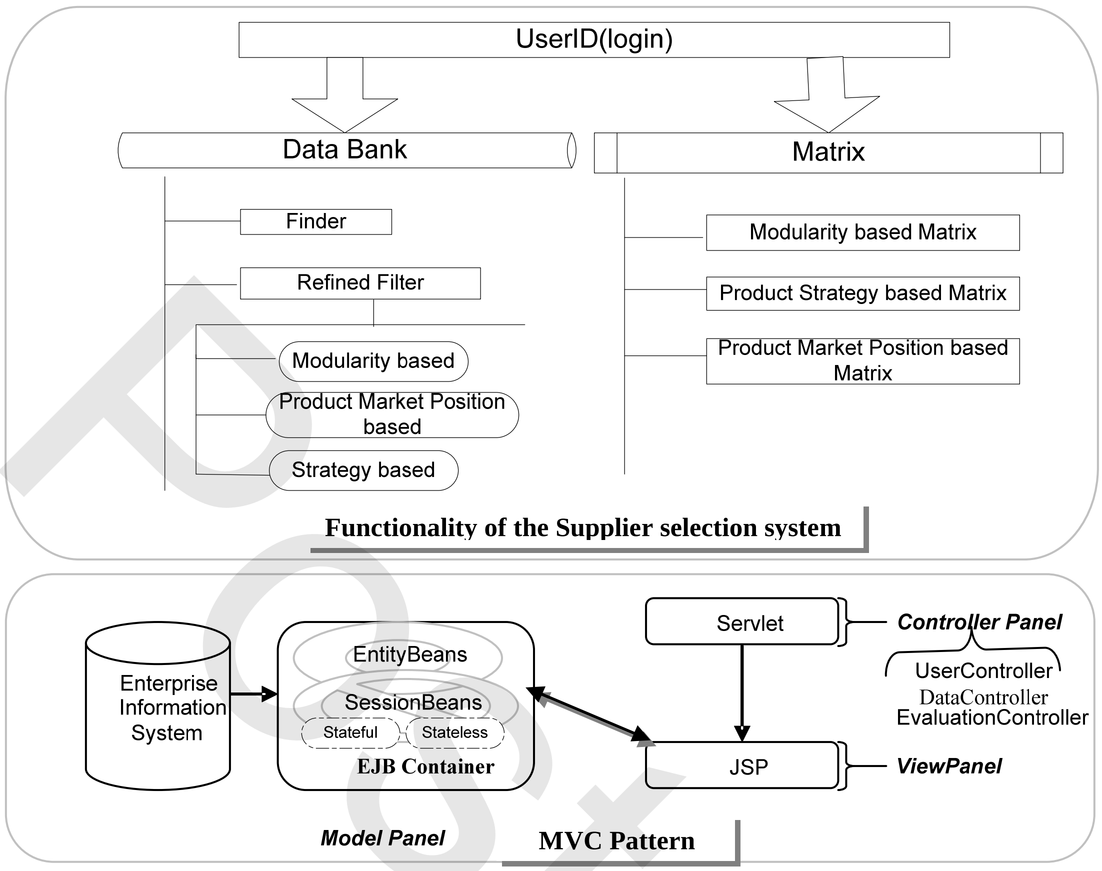

Figure 2 Architecture and Functionality of the EJB-MVC Oriented Supplier Selection System

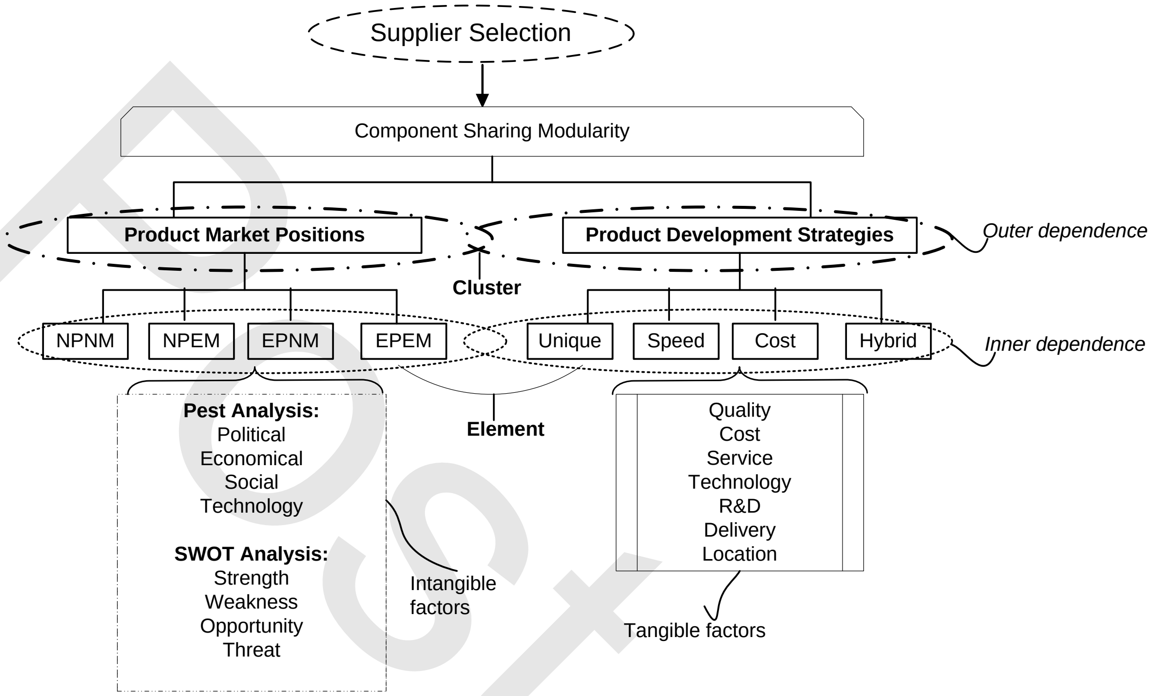

Figure 3 Structure of AHP/ANP based Supplier Selection for Mass Customization

Specification for Centre Coil Spring		Specification for Air Value Coil Spring	
Wire diameter	Ø0.16±0.005mm	Wire diameter	Ø0.45±0.02mm
Inner diameter of coil	Ø2.53±0.1mm	Inner diameter of coil	Ø4.2±0.1mm
Total number of coils	16.5±	Total number of coils	13
Number of active coils	11	Number of active coils	5
Spring constant	0.0234 N/mm(2.31gf/mm)	Load(Assembling)	2.52±0.25 N(200±20gf)
Load	0.0523±0.0018 N(5.2±0.2gf)	Height(Assembling)	10mm
Height	3.5mm	Stress(Assembling)	269MP (24.56kgf/mm^2)
Stress	63.5MP(8.11 kgf/mm^2)	Load(Operating)	3.12±0.3 N(250±25gf)
Free height	5.8	Height(Operating)	9mm
		Stress(Operating)	340MP (28.56kgf/mm^2)
		Free height	Less than 15

Table 1: Components Specifications

Speed	NPNM	NPEM	EPNM	EPEM	Rating
NPNM	1.000	0.500	0.333	0.250	**0.097**
NPEM	2.000	1.000	0.500	0.333	**0.165**
EPNM	3.000	2.000	1.000	2.000	**0.399**
EPEM	4.000	3.000	0.500	1.000	**0.339**

Table2:Paiwise comparison between product market positions cluster

EPEM	Political	Economical	Social	Technology	Strength	Weakness	Opportunity	Threat	Rating
Political	1.000	0.500	4.000	3.000	2.000	5.000	6.000	7.000	**0.209**
Economical	2.000	1.000	5.000	6.000	3.000	7.000	4.000	8.000	**0.309**
Social	0.250	0.200	1.000	2.000	4.000	8.000	5.000	6.000	**0.150**
Technology	0.333	0.167	0.500	1.000	5.000	8.000	6.000	7.000	**0.151**
Strength	0.500	0.333	0.250	0.200	1.000	2.000	3.000	7.000	**0.085**
Weakness	0.200	0.143	0.125	0.125	0.500	1.000	0.333	2.000	**0.030**
Opportunity	0.167	0.250	0.200	0.167	0.333	3.000	1.000	2.000	**0.044**
Threat	0.143	0.125	0.167	0.143	0.143	0.500	0.500	1.000	**0.021**

Table3: Pairwise comparison of the PEST and SWOT criteria under product market positions cluster for EPEM

Speed	Technology	R&D	Quality	Service	Cost	Location	Capabilities	Rating
Technology	1.000	3.000	2.000	0.500	5.000	4.000	6.000	**0.254**
R&D	0.333	1.000	3.000	2.000	4.000	4.000	5.000	**0.221**
Quality	0.500	0.333	1.000	2.000	4.000	8.000	6.000	**0.195**
Service	2.000	0.500	0.500	1.000	2.000	5.000	3.000	**0.167**

Cost	0.200	0.250	0.250	0.500	1.000	5.000	4.000	**0.083**
Location	0.250	0.250	0.125	0.200	0.200	1.000	5.000	**0.052**
Capabilities	0.167	0.200	0.167	0.250	0.250	0.200	1.000	**0.027**

Table4 Pairwise comparison of the tangible criteria under strategies cluster for speed strategy

Position Cluster	NPNM	NPEM	EPNM	EPEM
Political	0.265	0.298	0.227	*0.209*
Economical	0.104	0.111	0.225	*0.309*
Social	0.238	0.197	0.189	*0.150*
Technology	0.175	0.160	0.111	*0.151*
Strength	0.035	0.125	0.136	*0.085*
Weakness	0.079	0.026	0.062	*0.030*
Opportunity	0.049	0.051	0.032	*0.044*
Threat	0.054	0.031	0.019	*0.021*

Table5 Pairwise comparison of the PEST and SWOT criteria under product market position cluster

StrategyCluster	Unique	Speed	Cost	Hybrid
Technology	0.277	*0.254*	0.288	0.281
R&D	0.183	*0.221*	0.225	0.182
Quality	0.201	*0.195*	0.186	0.181
Service	0.110	*0.167*	0.113	0.114
Cost	0.141	*0.083*	0.099	0.151
Location	0.056	*0.052*	0.055	0.058
Capabilities	0.032	*0.027*	0.033	0.034

Table 6 Pairwise comparison of the tangible criteria under strategies cluster

	Unique	Speed	Cost	Hybrid	NPNM	NPEM	EPNM	EPEM
NPNM	0.466	0.097	0.091	0.419	0	0	0	0
NPEM	0.277	0.165	0.166	0.156	0	0	0	0
EPNM	0.161	0.399	0.24	0.242	0	0	0	0
EPEM	0.096	0.339	0.503	0.180	0	0	0	0
Unique	0	0	0	0	0.448	0.185	0.219	0.193

Speed	0	0	0	0	0.318	0.3931	0.413	0.176
Cost	0	0	0	0	0.129	0.187	0.125	0.218
Hybrid	0	0	0	0	0.104	0.235	0.242	0.413

Table7 Supermatrix

	Unique	**Speed**	**Cost**	**Hybrid**	**NPNM**	**NPEM**	**EPNM**	**EPEM**
NPNM	0.144	0.144	0.144	0.144	0	0	0	0
NPEM	0.097	0.097	0.097	0.097	0	0	0	0
EPNM	0.124	0.124	0.124	0.124	0	0	0	0
EPEM	0.133	0.133	0.133	0.133	0	0	0	0
Unique	0	0	0	0	0.005	0.005	0.005	0.005
Speed	0	0	0	0	0.006	0.006	0.006	0.006
Cost	0	0	0	0	0.003	0.003	0.003	0.003
Hybrid	0	0	0	0	0.004	0.004	0.004	0.004

Table8 Limiting supermatrix

	NPNM	**CSP**	**NPEM**	**CSP**	**EPNM**	**CSP**	**EPEM**	**CSP**
Political	0.265	0. 3816	0.298	0. 2891	0.227	0.2815	0.209	0.2780
Economical	0.104	0.1498	0.111	0.1077	0.225	0.2790	0.309	0.4110
Social	0.238	0.3427	0.197	0.1911	0.189	0.2344	0.150	0.1995
Technology	0.175	0.2520	0.160	0.1552	0.111	0.1376	0.151	0.2008
Strength	0.035	0.0504	0.125	0.1213	0.136	0.1686	0.085	0.1131
Weakness	0.079	0.1138	0.026	0.0252	0.062	0.0769	0.030	0.0399
Opportunity	0.049	0.0706	0.051	0.0495	0.032	0.0397	0.044	0.0585
Threat	0.054	0.0778	0.031	0.0301	0.019	0.0236	0.021	0.0279

Table9: Comparison results for product market positions cluster

	Unique	**CSS**	**Speed**	**CSS**	**Cost**	**CSS**	**Hybrid**	**CSS**
Technology	0.277	0.0139	0.254	0.0152	0.288	0. 0086	0.281	0.0112
R&D	0.183	0.0092	0.221	0.0133	0.225	0. 0068	0.182	0.0073
Quality	0.201	0.0101	0.195	0.0117	0.186	0. 0056	0.181	0.0072
Service	0.110	0.0055	0.167	0.0100	0.113	0. 0034	0.114	0.0046

Cost	0.141	0.0219	0.083	0.0050	0.099	0. 0030	0.151	0.0060
Location	0.056	0.0028	0.052	0.0031	0.055	0. 0017	0.058	0.0023
Capabilities	0.032	0.0016	0.027	0.0016	0.033	0. 0010	0.034	0.0014

Table10: Comparison results for strategies cluster

	Supplier1	**Supplier2**	**Supplier3**
Final Results	0.871	0.822	0.717

Table11: Supplier selection results under the component sharing modularity