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Modeling of Service Delivery System for Service Enhanced Product Design: An Approach to Improve Service Performance

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Abstract: In design of service enhanced product, Service delivery system should be properly modeled to promote service efficiency and economy. A new modeling method to describe detailed features of Service Delivery System was proposed. The method kernel is technical combination of Weighted Generalized Directed Graph (WGDG) with Extended Service Blueprint. Relationship weight was introduced to Generalized Directed Graph to build WGDG model which describes adjacent and accessible relationship and their types of functional departments related to Service Delivery System, at the same time qualitatively reflects significant of every relationship to Service Delivery System. In order to build connection of service with product, normal service blueprint was extended to not only describe interactive relationships of product with service and customer with enterprise but also, combined with WGDG, give hierarchical structure, interactive types and their circulations for all factors involved. By ensuring customer satisfaction and high service efficiency and economy, this modeling method lends a useful tool for development of service enhanced product.

Key words: Service delivery system, modeling, weighted generalized directed graph, extended blueprint

INTRODUCTION

Recently, because of severe market competition of industrial product, almost all manufacturing enterprises have to face rapid changing and more complicated customer demand. Less and less profit forces manufacturing firms to find new way to broaden their profitable space. Product-service is deemed to a main effective approach to increase extra benefit and profit (Berger and Lester, 1997). Some firms have already changed their strategic emphasis from providing mere product or service to offering a whole solution of product-service binding (Roy, 2001). Abundant demonstrations showed that design, development and implementation of service enhanced product are effective weapons for current manufacturing enterprises to extricate themselves from homogeneous competition, meet more and more complicated demand and get continuous profit increment. Practices indicated that, to occupy better market position, product manufacturers must combine product with necessary service to form Aproduct-service binding@ composed of product, technology, information and consideration (Shepherd and Ahmed, 2000; Stoughton and Votta, 2003; Meier and Krug, 2006; Meier *et al*., 2011).

Product-service binding has been mostly used in manufacturing of complicated and expensive industrial equipment such as top grade numerical control machines, aviation equipment, engineering machinery, automobile and etc. Because of high complexity of the equipment, suppliers and customers are always faced with various problems in all life cycle of the equipment from prophase planning, design, assembly, installation and debugging, production startup, operation to recycling. Most of these problems will affect equipment running directly. For customers, their buying motives are economic benefit and enhanced core competitive power. Therefore, it is very important to provide reasonable service throughout equipment lifecycle.

A key topic in development of service enhanced product is how to improve performance of Service Delivery System. Related topics have been widely studied through different approaches. Aimed at application of informal control to improve supplier performance in internal service exchanges, Stouthuysen K, Slabbinck H and Roodhooft F proposed that the actual effect of formal control depends on its mode (output vs behavior) and its relationship with the service type (mass vs professional) and informal control (Stouthuysen *et al*., 2012). With theory of multiple objective optimization, Sun *et al*. (2012) analyzed relationships among service provider candidates, service types and parameters to find out the best part machining service provider combination. For embedded knowledge service application in mechanical

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product development, Meng and Xie (2011) analyzed key problems such as the decomposition of design tasks for cross-organizational assignment, the search of partners, the evaluation of the resources units and the information transfer from the design entities to the resources units. Schleimer and Shulman (2011) knitted a more comprehensive and cohesive understanding of the differences between new service development and new product development success as the result of different patterns of collaboration. They argued that there is a stronger, positive relationship of intensity levels of joint engagement among firms involved in product development and performance than when a new service is developed. Focusing on service delivery to machine tool users, Greenough and Grubic (2011) described development and validation of two software tools to explore the relationship between prognostics and health management technologies and servitization in the machine tool industry. From 225 firms across the value chain, ranging from service providers and systems integrators to component and material suppliers in the UK aerospace industry, Angelis and Thompson (2011) showed that the combination of high employee involvement and aligned human resources and industrial relations allows firms to achieve higher performance. Lee and AbuAli (2011) presented an operating system for innovation by offering a methodology for systematic innovative thinking and a toolbox of interconnected tools that can aid in the transformation of core product competencies into effective product-service amalgamations. In order to offer better support for the rapid product development of small and medium sized enterprises (SMEs), Lan *et al.* (2003) developed a networked service system of Rapid Prototyping and Manufacturing (RP and M) and presented a novel framework of RP and M networked service system.

Former researches give an effective promotion to development of product-service. However, for service enhanced product, it is necessary to provide service efficiently and economically. In the product development, Service Delivery System should be properly modeled to show detailed system patterns to promote service efficiency and economy. Therefore, it should be emphatically considered to ensure customer satisfaction and high service efficiency. In this paper, a new modeling method to describe detailed features of product-service will be proposed.

REQUIREMENT ANALYSIS

In planning process of service enhanced product, in order to promote service efficiency and economy, Service Delivery System must meet the following requirements:

- Clearly describe interactive relationship between product and service
- Clearly describe delivery flow and contact points between functional departments which help to find key points to improve customer satisfaction and service quality
- Be advantageous to system optimization and planning change to realize transfer process reconfiguration and rapid response to customer demand and enterprise resource change
- Reduce delivery time and cost
- Ensure service quality, efficiency and reliability
- To meet above requirements, more attention should be paid to the modeling process of Service Delivery System
- To reduce transfer route and increase transfer efficiency, transfer chains of information, resources and functions between service activities should be as short as possible
- Information should be transferred as possible within the same functional department. Too much cross transfer between different functional departments should be avoided
- System model can clearly describe not only interactive relationship between product and service and different functional departments but also relationship types and their significance to service performance improvement to find improving and optimizing for improvement and optimization
- System model can reflect hierarchical structure of functional departments to find interactive points between departments and then find customers' main experience points and improved focuses

With flowchart, service blueprint is a useful tool to describe service transfer process accurately. Through continuous description of service providing process, customer experience process is directly shown with service encounter, employee' and customers' roles and visible evidences. Figure 1 gives a normal pattern of service blueprint.

Service blueprint reasonably divides service to providing steps, tasks and their realizing methods. It is especially important that key points of customer experience and interactive points of customer with enterprises can be directly analyzed and judged and then improving focuses of customer perceptive value can be found. In modeling of Service Delivery System, these experience points, interactive points and improving focuses should be emphatically considered.

For service enhanced product, however, available service blueprint didn't consider physical product and couldn't describe interactive relationship between

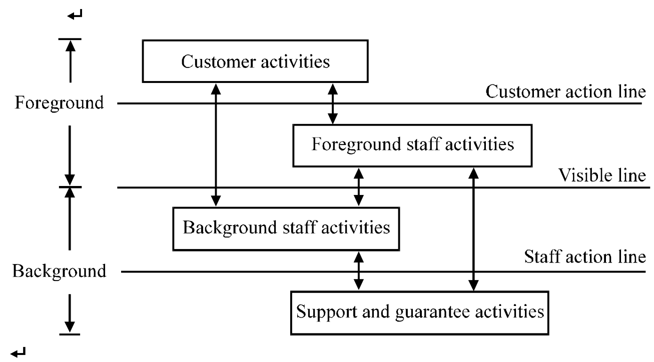

Fig. 1: Normal pattern of service blueprint

product and service. Existing blueprint should be extended, through adding physical elements, to describe interactive relationships of product with service and customer with enterprise. Additionally, for more involved functional departments and service activities, complicated mutual constraints and correlative relationships made simple flow analysis adopted by normal blueprint not meet the modeling requirements. Source of above problem is that there exist not only interactive relationships in delivery process but also various interactive types including function flow, resource flow, information flow, capital flow and so on. Namely, blueprint couldn't show features of interactive types and their circulation.

Generalized Directed Graph (GDG) can clarify relationship between factors within complex system, build system structural model accurately and rapidly and describe every factor and its circulating information. Above features help enterprise to improve Service Delivery System to promote delivery efficiency and economy by description of concrete flow type. Only reflecting relationship types, however, GDG cannot qualitatively reflect relationship between two factors. An element, relationship weight, would be added to GDG to build model of Weighted Generalized Directed Graph (WGDG). The model not only describes adjacent and accessible relationship and their types but also qualitatively reflects significant of every relationship. With WGDG construction and extended service blueprint, Service Delivery System could be explicitly modeled.

WGDG BASED MODELING

WGDG model: Because of factor diversity and relation complexity, including all factors and their relationships in WGDG will increase modeling complexity and analysing difficulty. Therefore, factors in the same functional department was grouped into a generalized module (customer and product, respectively regarded as individual department). WGDG model G of Service Delivery System could be expressed as follows:

$$G = \langle V, E, T, \Psi, W \rangle \tag{1}$$

Where:

- V = Department set
- E = Flow set composed of edge vectors to reflect interactive routes and their direction
- T = Definition domain of directed edge which elements are natural number and each number represents a flow type. T satisfies relation $E_i \subseteq T$ and:

$$T = \bigcup_{i=1}^{m} E_i$$

Table 1 gives basic flow types in delivery system

- Ψ = Mapping of ordered pairs from E to V. Fig. 2a, for example, shows a simple WGDG model of maintenance service. Where v1 denotes failure analysis, v2 maintenance planning, v3 failure parts disassembly, v4 spare parts collection, v5 failure maintenance and v6 delivery. Flow types were represented by figures (1) Information flow, (2) Capital flow, (3) Function flow, (4) Resource flow and (5) Knowledge flow. Mapping of ordered pairs from E-V (Ψ) was shown by Fig. 2b
- W = Which value w_{ij}^k represents dependent weight between departments i and j for relationship k. Because dependent weights have great uncertainty and fuzziness, the weights could be judged by sensitivity of interactive activities to this relationship and relationship alterability (Wang, 2003). Here scale 0-0.9 was adopted to

Table 1: Basic flow type in service delivery system

Flow types	Flow values
Information	Customer demand information
	Market information
	Policy information
	Capacity information of resource and service of enterprises
	Supply chain information
	Service task information
	Basic information of equipment, such as function, performance, structure, appearance and so on
	Running information (failure, running state, running environment, productivity, production quality)
	Service task planning information
	Service task execution information
	Customer feedback
Capital	Manpower cost
	Transaction cost
	Use-cost
	Service cost
	Infrastructure construction cost
	Price of service enhanced product
Function	Material
GAO *et al.* (2005)	Energy (bioenergy, mechanical energy, electric energy, thermal energy, chemical energy)
	Signal (state signal, control signal)
Knowledge	Customer knowledge
	Maintenance knowledge
	Management knowledge
	Operating knowledge
	Manufacturing knowledge for equipment
	Service knowledge
	Financing knowledge
	Marketing knowledge
	Sociology knowledge
Resource	Manpower
	Material resource
	Supply chain resource
	Production resource
	Technical resource
	Channel resource
	Customer resource

quantify dependent weights. In Fig. 2a, weights of information flow and knowledge flow to maintenance planning are 0.5 and 0.4, respectively

Generalized adjacent matrix construction: Based on WGDG, generalized adjacent matrix for Service Delivery System could be built to describe direct relationship between departments. For Service Delivery System with n functional departments, define generalized adjacent matrix A as:

$$A=[M(v_i,v_j)]=\begin{bmatrix} 0 & m_{12} & \cdots & m_{1n} \\ m_{21} & 0 & \cdots & m_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & \cdots & 0 \end{bmatrix} \quad (2)$$

Where:

$$m_{ij}=\sum_{k=1}^{m} p_{ij}.w_k$$

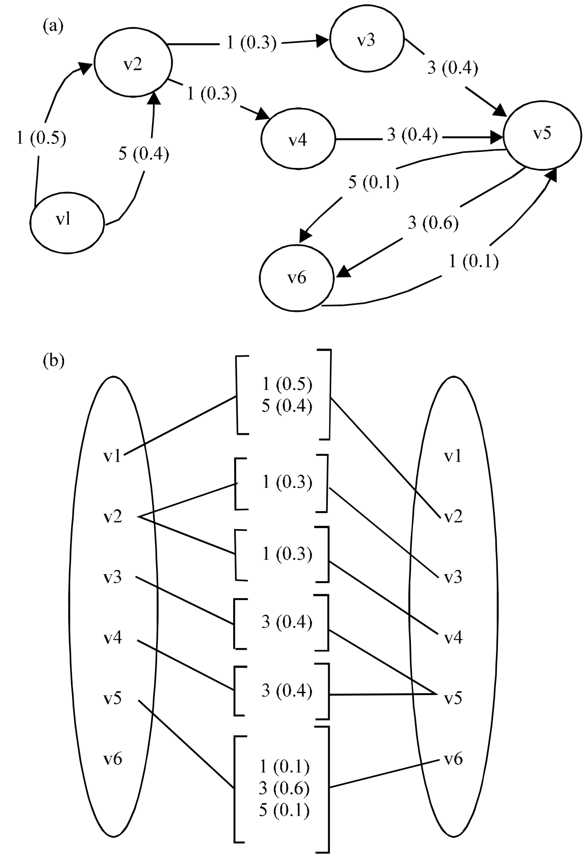

Fig. 2: Simple WGDG model of maintenance service

$$p_{ij}=\begin{cases} 1, \text{ Functional department } p_i \text{ has direct influence or relationship to } p_j \\ 0 \text{ Functional department } p_i \text{ has no direct influence or relationship to } p_j \end{cases}$$

w_k expresses relationship weight.

Accessible matrix construction: Through calculation of generalized adjacent matrix, accessible matrix could be given to describe indirect relationships between functional departments. Accessible matrix denotes, through a certain length route, whether nodes in WGDG can reach each other or not. For Service Delivery System, accessible matrix shows the distance of cooperative or interactive route between various functional departments and reflects the interactive deepness of a department with another. Accessible matrix R is a square matrix which elements could be given as following:

$$r_{ij}=\begin{cases} 1: \ v_i \text{ can access } v_j \\ 0: \ v_i \text{ cannot access } v_j \end{cases}$$

Based on A, R can be calculated by the following equation:

$$R = \bigcup_{l=0}^{n-1} A^l = (A \cup I)^{n-1} = (A \cup I)^n \qquad (3)$$

In practice, R could be sometimes given in less than n times of calculations. Following calculation steps had been given by Chen and Xiao (2008).

In practice, R could be sometimes given in less than n times of calculations. Following calculation steps had been given by Chen and Xiao (2008):

$$\begin{cases} A_1 = A + I \\ A_2 = (A+I)^2 \\ \vdots \\ A_{r-1} = (A+I)^{r-1} \\ R = A_r = A_{r-1} \neq A_{r-2} \neq \cdots \neq A_1 \end{cases} \qquad (4)$$

Accessible matrix decomposition: The purpose of accessible matrix decomposition is identifying the hierarchical relationships between functional departments. Suppose R_e be the equivalent matrix of accessible matrix $R = (r_{ij})_{n\times n}$:

$$R_e = R \cap R^T = (\bar{r}_{ij})_{n\times n} = (r_1, r_2, \cdots, r_n)^T \qquad (5)$$

where, r_i (i = 1, 2,Y, n) is a n-dimension row vector. All unequal r_i will form a set $\{r_1, r_2,..., r_m\}$, $1 \leq m \leq n$. If a row vector r_i has more than one components which value is 1 and these components in r'_1, $(1 \leq i \leq m)$ are expressed by r_{ik1}, r_{ik2}, r_{ikt}, $2 \leq t \leq n$, then the subsystem $S' = \{v_{k1}, v_{k2},..., v_{kt}\}$ is a connected subset. For a connected subset, longer interactive route means more functional departments involved.

Service blueprint for service delivery system: For Service Delivery System of service enhanced product, it is necessary to describe interactive relationship between physical product and service clearly. An improvement of above mentioned blueprint was firstly needed. In extended blueprint, action domain was divided to customer activities, foreground staff activities, background staff activities, cooperative partner activities and product. Figure 3 shows the pattern of extended blueprint model.

By accessibility of functional departments, department with longest connected subset was set at the highest level in service blueprint, then remove this connected subset and find another longest subset in rest subsets. Repeat above steps until all functional departments had their level locations in service blueprint. Through WGDG analysis, flow types between departments could be defined and expressed in blueprint. Factors and their relationship in each department could be further defined with analysis of delivery flow chat. Delivery system model was finally built by detailed description of hierarchical model.

CASE STUDY

Here, modeling process of a Service Delivery System for maintenance service of spindle system of a certain NC machine was discussed. According to service activities, service flow was mapped as Fig. 4. To construct WGDG, service flow was converted to interactive relationships of functional departments, shown by Fig. 5.

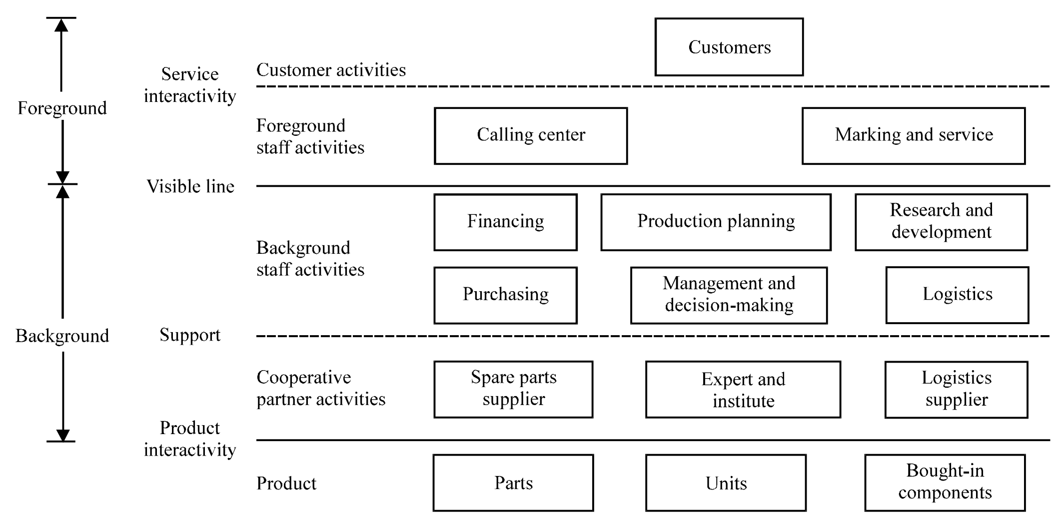

Fig. 3: Extended service blueprint mode

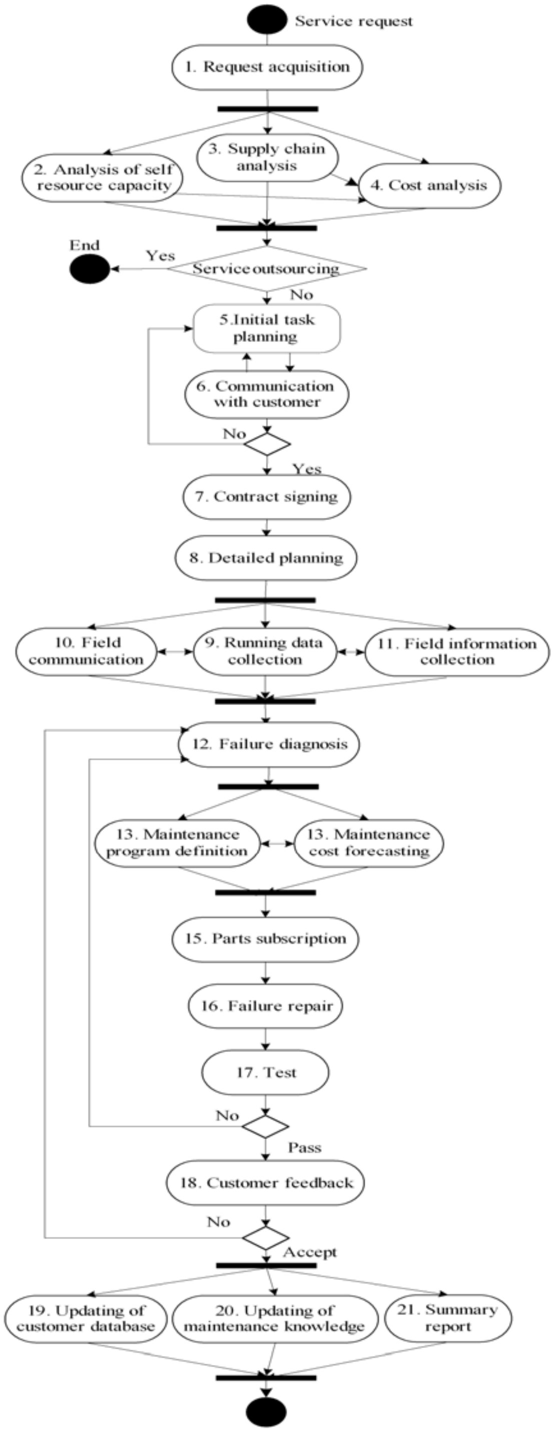

Fig. 4: Service flow of maintenance service

In Fig. 4, functional departments of the delivery system were defined as follows (1) Customer, (2) Calling centre, (3) Marketing and service department, (4) Outsourcing supplier, (5) Maintenance centre, (6) Maintenance staff, (7) Purchasing, (8) Spare parts supplier, (9) NC machine and (10) Spare parts. Based on Fig. 4 and 5, WGDG for maintenance service could be built as Fig. 6. Table 2 is the meaning of directed edges.

Table 2: Meaning of directed edges in Fig. 6

Flow type	Information	Capital	Function	Resource	Knowledge
T	1	2	3	4	5

Table 3: Transformation of accessible matrix

Functional department	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
①Customer	1	1	1	1	1	1	1	1	1	1
②Calling centre	0	1	1	1	1	1	1	1	1	1
③Marketing and service	0	1	1	1	1	1	1	1	1	1
④Maintenance centre	0	0	0	1	1	1	1	0	1	1
⑤Maintenance staff	0	0	0	1	1	1	1	0	1	1
⑥Purchasing	0	0	0	0	0	1	1	0	0	1
⑦Spare parts supplier	0	0	0	0	0	0	1	0	0	1
⑧Outsourcing supplier	0	0	0	0	0	0	0	1	1	0
⑨NC machine	0	0	0	0	0	0	0	0	1	0
⑩Spare parts	0	0	0	0	0	0	0	0	0	1

Based on Fig. 6, adjacent matrix A corresponding to WGDG could be given by Eq. 6.

Then accessible matrix R (7) could be calculated by time calculation of adjacent matrix A:

$$A = \begin{bmatrix} 0 & 0.8 & 0.5 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.5 & 0.8 & 0 & 0.8 & 0 & 0 & 0 & 0.9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 & 0 \\ 0 & 0 & 0 & 0 & 0.9 & 0.7 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0 & 0 & 0 & 0 & 0.5 & 0.2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.4 & 0 \end{bmatrix} \begin{array}{l} \text{1) customer} \\ \text{2) calling-} \\ \text{3) marketing-} \\ \text{4) outsourcing-} \\ \text{5) maintenance centre} \\ \text{6) maintenance staff} \\ \text{7) purchasing} \\ \text{8) spare parts-} \\ \text{9) NC machine} \\ \text{10) spare parts} \end{array} \quad (6)$$

$$R = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{array}{l} \text{1) customer} \\ \text{2) calling centre} \\ \text{3) marketing-} \\ \text{4) outsourcing-} \\ \text{5) maintenance centre} \\ \text{6) maintenance staff} \\ \text{7) purchasing} \\ \text{8) spare parts-} \\ \text{9) NC machine} \\ \text{10) spare parts} \end{array} \quad (7)$$

All rows of R were sorted by the number of elements which value is 1. Table 3 could be given by row-column transformation according to the accessible relationship of each functional department to the others. By Table 3, it was known that customer could access all functional departments (every element of the first row is 1) and would be located at the highest level. Calling center and Marketing and service department could access all other departments except Customer and was located at the second level. Based on Table 3, all departments could find their level locations and mutual connecting relationships.

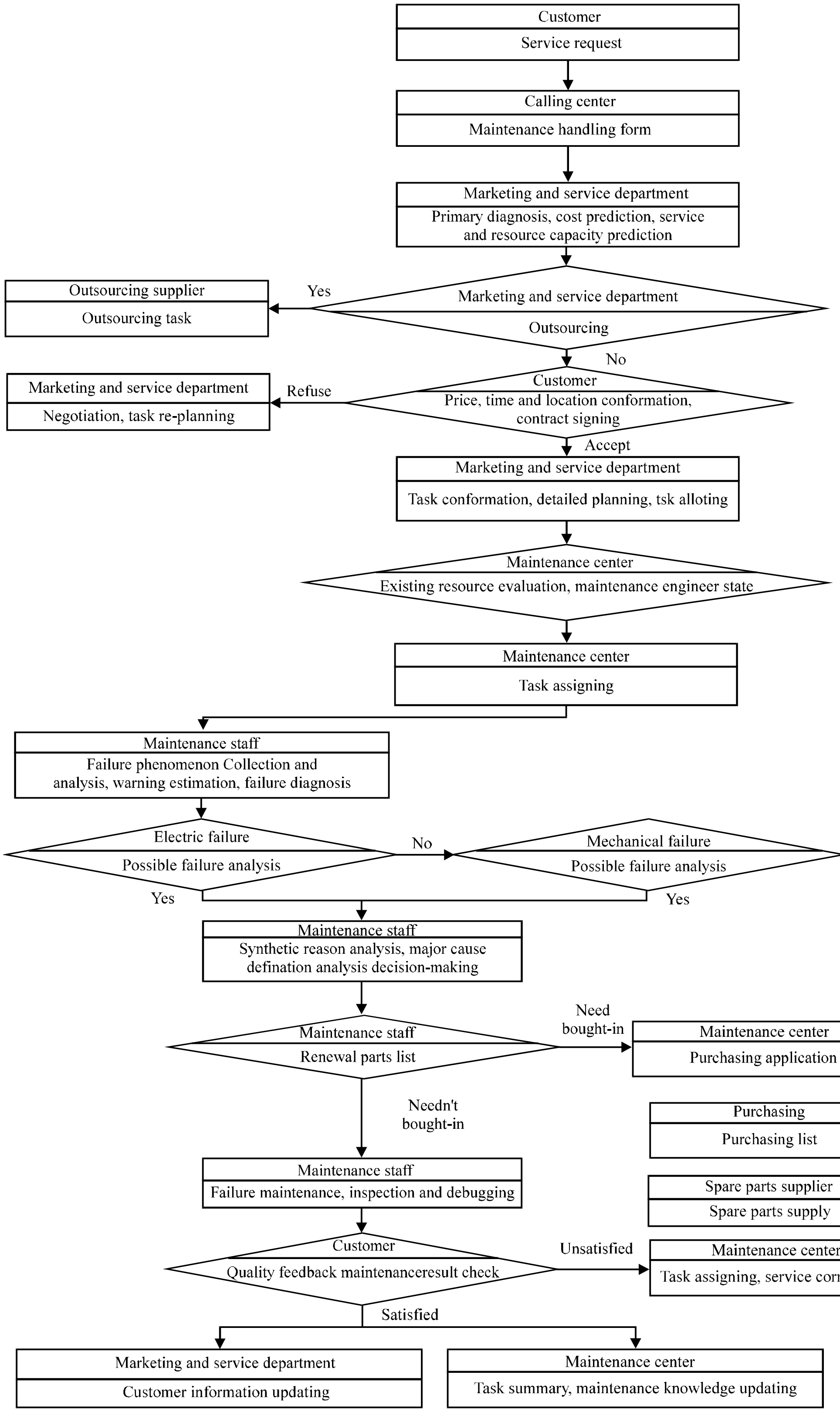

Fig. 5: Interactive relationships of functional departments

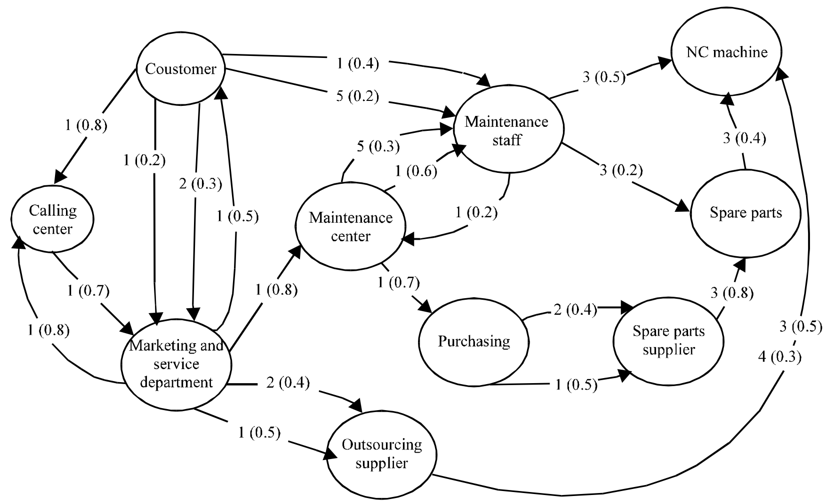

Fig. 6: WGDG for maintenance service of a NC machine

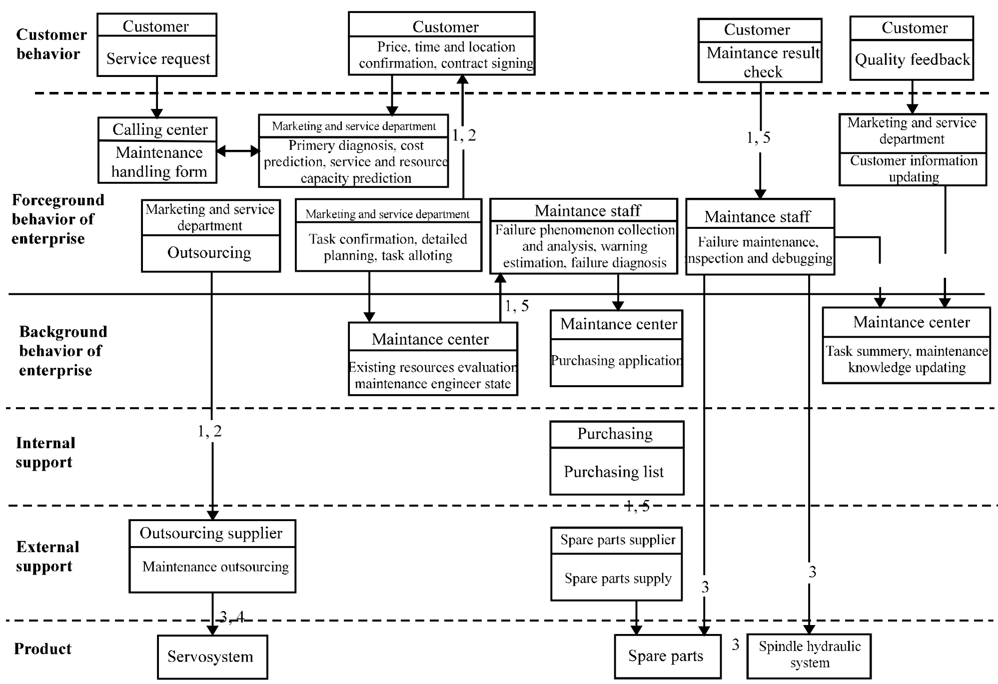

Fig. 7: Departments based service blueprint model

Because maintenance staffs closely contact with customer, their attitude and technical level will directly affect customer experience, maintenance staff was put at the second level though it located at the third level.

According to delivery flow, service blueprint was further refined to define service flows of every department and interactive relationship types between departments. Departments based service blueprint model was shown by Fig. 7 (detailed internal service flows of every department were not given).

CONCLUSION

Aimed at service enhanced product, a modeling method for Service Delivery System was proposed above. The kernel of this method is technical combination of Weighted Generalized Directed Graph with Extended Service Blueprint.

For service enhanced product, it is necessary to provide service efficiently and economically. Therefore, in modeling of Service Delivery System, it should be emphatically considered to ensure customer satisfaction and high service efficiency which requires Service Delivery System having efficient information transfer, including binding of service and product, describing mutual relationships between functional departments, showing relationship types and their significance to service performance, reflecting hierarchical sequence of department to find their interactive points and helping to find customer key experience points and improving focuses.

Normal Generalized Directed Graph only reflects relationship type between factors and cannot qualitatively analyze and reflect relationship between two factors. Relationship weight was introduced to GDG to build model of Weighted Generalized Directed Graph (WGDG). For functional departments, WGDG describes adjacent and accessible relationship and their types, at the same time qualitatively reflects significant of every relationship to service delivery.

In order to build connection of service with product, normal service blueprint was extended. Extended blueprint not only describes interactive relationships of product with service and customer with enterprise but also, combined with WGDG, gives hierarchical structure for all factors involved in delivery process. Also, extended blueprint shows the features of interactive types (including function flow, resource flow, information flow, capital flow and so on) and their circulation in service flow.

With above Service Delivery System model, the required attributes for efficient and economic service providing can be found. Further study should focus on how to define principles to classify service activities and their impact on development of service enhanced product, find reconfiguration method for service or product functions to realize product-service binding really.

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