Studies of Enterprises' Modularization Decomposition

Tao Wu[1], Wenjin Wu[2], Shuojia Guo[1], Ronqiu Chen[1]
1 Management school, Huazhong University of Science and Technology, Wuhan, 430074, wut@wuhan.gov.cn
2 Economic and Management School, Wuhan University, 430072

Abstract. "Modularity" theory has been widely applied in product design and manufacturing, system development etc., meanwhile the notion of "modularity" has been infiltrating into researches and practicalities of current enterprises theories, industrial economy as well as enterprises strategies. Thus, the concept of "modularity" is a hot topic among experts of products design engineering, economist and operating specialists. Based on modularity classification researches to global product functions, through the logical integrate analysis of function-theory-method-entity, combined with relations upon the four levels, this paper puts forward one enterprises modularity decomposition method, which not only explains the variation of enterprises' structure, but also provides research clues for enterprises' modularity integration.

1 Theory and application of "Modularity"

Aoki Masahiko takes "modular" as a semi self-restrained subsystem, constituting together with other similar subsystems by certain rules into even more complicated system or process. He calls the complex unit or system decomposing into semi self-restrained lower unit as modularization; He therefore regards modularization as an effective method [1] to solve complicated system.

In researches of modularity structure and construction, Kusiak [2] has applied elicitation diagram modular identification and put forward three modularization structure designs; Gu [3, 4] and his colleagues put forward the optimal design of the integrated modularization design based on life cycle and integrated modularization design; By function design research in manufacturing and assembling, Tsai [5] and his colleagues have obtained the optimal method of modular construction, they also arranged the modular design and manufacturing

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sequence; Salhieh [6] etc have decomposed the construction process of modular into four stages and formed modular through the connected degree of characteristic index among spare parts.

In modularity decomposition researches, mechanical engineering takes the decomposition of the system, namely products, as key to concept design. Azarm and his colleagues (1989) studied the method of component-oriented decomposition [7]. Buur (1990) studied the discipline-oriented decomposition method [8], Hansen (1995) studied the function-oriented decomposition method [9], among which the function-oriented decomposition is applicable and hence is widely practiced, while the function method tree is one of its typical representatives. This method suits both simple system and complicated system concept designs.

2 Application analysis of modularity in enterprise

Through the proportion developed by modularization unit's supplier and automobile assembling factory together(15% in North America, 52% in Japan), and therefore the finished auto costs advantage analysis, Clark and Fujimoto (1990), point out that the modularization unit is a new and efficient topic of operation pattern and unit type. They conclude enterprise operates on the basis of modularization unit, taking the entire production network as unit, not refining only within a single enterprise [10].

Through the establishment of enterprises' inner market, by market pricing method, it thus enables the intermediary products to flow within enterprises and combines enterprises' interior and exterior markets together. Therefore, modularization unit is more adaptable, directed and flexible. It requires each modularization unit in enterprise to become independent Business Entity with "Self-Organization". They are some self-existing, self-evolution and self-progressing economic entities.

In the operation level, application of modularization in enterprise mainly reflected in three aspects: First is the business modularization established on the basis of reengineering theory. Second is the capability elements modularity based on the core ability. Third is unit structure modularization on the basis of system engineering theory. So, modularization operation in enterprises can be understood from two aspects: first is to construct enterprises' unit modular by business modular and core capability, reacting swiftly to requirements of the exterior market, namely enterprise's modularization integration; Second is to decompose enterprises into some modularity units by certain structure, level and regulations and to take the business modularity and core ability modular as its content. This paper attempts to put forward an enterprise modularization decomposition method through the integration analysis of the logics among function-principle-method-entity.

3 Decomposition system of Enterprises' modularity's function-principle-method-entity

3.1. Function tree expression of enterprise

As a system, enterprise owns certain function. To take function as the abstract expression of enterprise system not only helps to summarize the diversification of enterprise entity structure, but also helps to decompose enterprise with systematic engineering method. For example, enterprise has a general function to supply product(service) to market, directed to this, there can be many different entity types of enterprise corresponding(such as productive enterprise, distributing enterprise, retailing enterprise, etc) to fulfill this total function. As an abstract concept, function can be realized by different entity objects. So, relation between function and its realized entity is one to several. In this way, it is an effective enterprise analysis method to abstract different individual enterprise systems into the function area for systematic decomposition and analysis.

We can use the function tree method in the systematic engineering principle to decompose enterprise after abstracting enterprise system to the function area, so that we can ascertain a reasonable function unit and function structure to fulfill the overall function. The function tree expression is shown in Figure 1 where OF refers to the overall function and F refers to function.

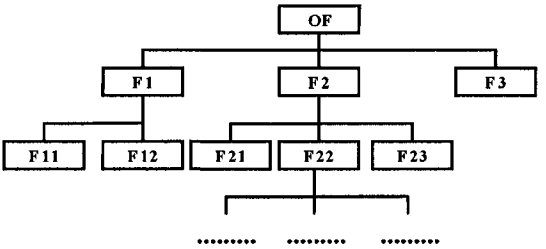

Fig. 1. Sketch Map of Function Tree

3.2 Expression of enterprise's function-principle tree

The traditional function decomposition method only conducts in the function area, there exists on the one side the difficulty of function's reasonable decomposition, and it is difficult on the other side to get the complete defined collection of sub functions. So, according to Axiomatic Design (AD) theory, to correspond principle with function and to join the function decomposition can not only support theoretically function's realization, but also ascertain the suspending stage of function decomposition through the function corresponding principle realization.

To better express and support theoretically the earlier mentioned function decomposition, reference [11] forwards the principle figure of function method tree. This paper puts forward the sketch map of the function-principle tree as shown in Figure 2: P refers to principle, OF is the root, namely the overall function to be modularized, the bottom (P11, P31, P31, P33, etc) is a series of principles. So, a function can be supported both by only one principle and by multi principles. Relation between function and principle is one to several in the same level. On the contrary, principle's produced function is relation at different levels; their relation can either be one to one, or one to several.

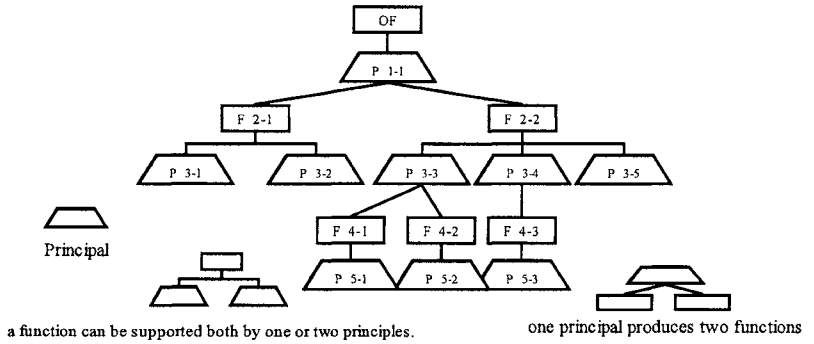

Fig. 2. Sketch Map of Function-Principle

3.3 Principle-method corresponding relation

Principle acts as functions' theoretical support while method is the practice to realize function under the guidance of principle. Obviously, one principle corresponds to several methods, that is to say, backed by one principle, one function can be achieved by different methods in various environment and background. Method is unlike function and principle, which exist level structure, it is the specific practice to realize functions, backed by one principle and in different environments and backgrounds. Method is different from function and principle existing level structure, it is the collection of specific practice and it is hard to express with level area.

3.4 Enterprise entity system tree expression

The traditional enterprise entity analysis is established on the unit modularity basis of the level structure, it is in fact a kind of systematic decomposition method, with the same principle and pattern like the function decomposition. It is actually the

materialized pattern of the function, and it has the same framework of function tree.

3.5 Enterprise system function-principle-method-entity decomposition system

According to the Law [11] in the mechanical system, in the mechanical system, there exists casual relation between function and method, function is realized by method, method corresponds to a series of entities, and the entity's action result is solution to function. Putting this Law into social and economic system, this paper forwards function-principle-method-entity solution system of enterprise system modularity decomposition system.

Function system coming out of decomposing the traditional function tree is called as the function area. Also, principle and entity modular have their principle areas and modularity areas respectively, as various methods can hardly be integrated within one level; we sum up all the methods into method sets in this paper.

Directed by the same theory, under different restrictions, we can achieve function target through various methods. Law takes that a method usually corresponds with a series of entities. In this paper, we define enterprise as a modular, so enterprise is composed of related sub modular. We conclude hence that method corresponds with each sub modular in enterprise. To integrate function area, principle area, method sets and modular area together as to construct an enterprise modularity decomposition system just as what is shown in Figure 3.

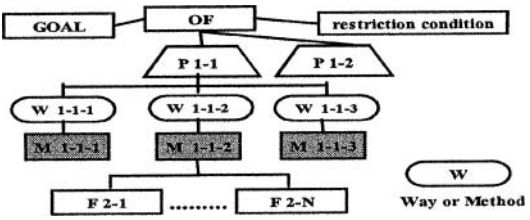

Fig. 3. Enterprise Modularization Decompositions Illustration Based on Function-Principle-Method-Modular Integration

In Figure 3, relation between the function area and the principle area is one to several; relation between principle area to method sets is also one to several. Only relation of method sets to modular area is one to one as shown in Figure 4. So, directed to this function, under the support of certain principle, with various methods, it can be fulfilled by different modular entities, this can explain functionally the diversification of enterprise structures and unit patterns.

4 Determination of enterprise function-principle-method-entity decomposition system

Within enterprises' function-principle-method-entity decomposition system, the decomposition floor issue concerning function and modular decomposition, namely the end level of enterprise modularization decomposition determination is an important content of modularity decomposition. It decides the facilitation and feasibility of bottom modular function realization after the modularity decomposition.

4.1 Floor function determination of the mechanical system

In function bottom determination of the mechanical system, Sturges [12] points out that the functional decomposition should stop when function decomposition reaches supporting functions, while supporting function is "a common model of usual component, process or sub function", yet he does not offer any supporting function sets. Kirschman [12] puts forward a systematics based on function after the analysis of various machines like automobile, driller and weeder, namely the four basic functions of movement, control, energy and connection; he describes the four basic functions with four types of languages and therefore constitutes the classification of the basic functions. Through researches of the realization method of basic functions, he sets up the method base of basic functions; any method within the base can become the bottom method of function tree and therefore may correspond directly to the bottom entity structure.

4.2 Determination of the bottom modular in enterprise system decomposition

If the specific method can correspond with the existed parts, or the designer considers the method is actually easily realized in practical systematic decomposition, then these methods are the floor methods and entity corresponding to this method can be understood as the bottom physical entity.

Each sub modular that enterprise modular gets after the modularity decomposition differs from modular in products and physical system (such as mechanical system and software system, etc), because it includes human elements. So, in enterprise modularity decomposition, determination of modular bottom may consult the determination method of function bottom in mechanical system, through the integrate analysis of function-principle-method-modular, the following flow design diagram of floor function-entity modularity is put forward, see Figure 5.

First, directed to entity system, to determine construction of system's (modular) abstract overall function, decomposing the overall function in the function area, it is obvious that there will be related principle to support it in each decomposition function level.

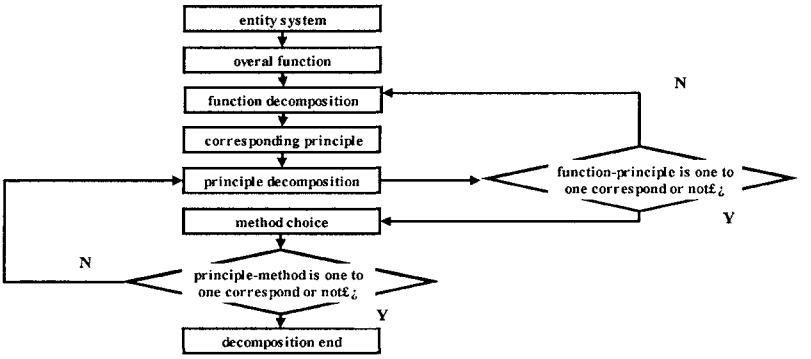

Fig. 5. Sketch Map of Floor Function-Modular Determination Process

Second, after the determination of the overall principle of the general function, find out the corresponding function supporting principle in the function area and calculate the corresponding relation between principle and function. If in the two areas, the corresponding relations are one to one, then we should choose the corresponding methods; if it is not one to one relation, and then continue the function decomposition program.

Third, judge whether principle corresponds with method one by one or not, if it corresponds one to one, then bottom method will decide, and stop the decomposition of function and modular; if principle does not correspond with method, then return to the principle decomposition program.

As this paper defines that relation between method and modular is that of one to one, so in the calculation illustration, bottom method should correspond to the bottom sub modular.

5 Modularity Decomposition Analysis of enterprise production system based on demand satisfaction principle

Production system is a sub system in the enterprise system whose main function is to produce. While products determine the production system needed, what to produce is determined according to market requirements. Satisfaction of customer demand is the supporting principle of the production system in manufacturing. Only to produce what customers need enables effective realization of the production system. This paper analyzes briefly the modularization decomposition process on the basis of enterprise production system of satisfaction principle, seen in Figure 6.

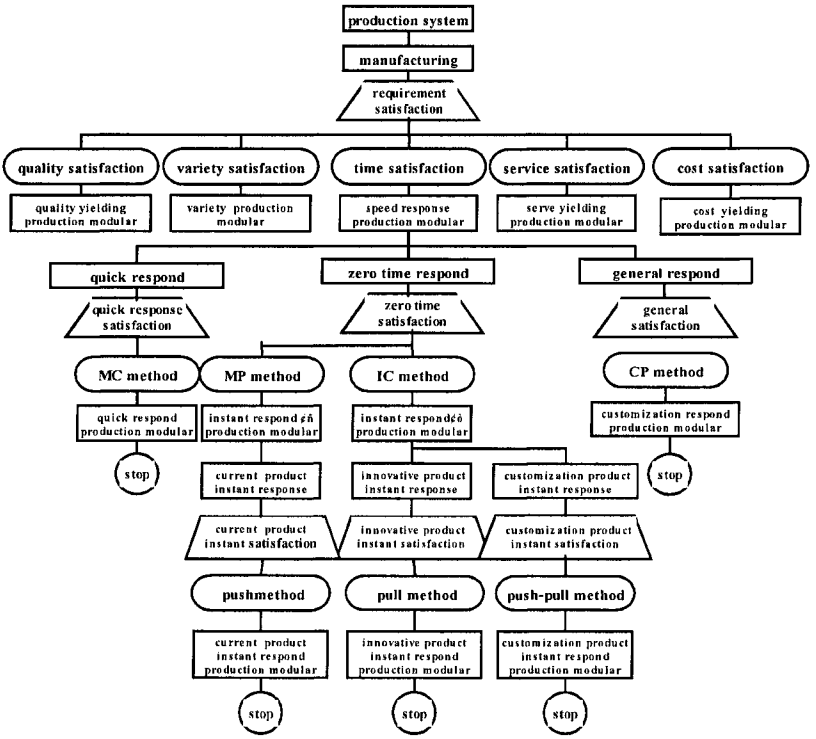

Fig. 6. Sketch Map of Modularity Decomposition of the Production System Based on Requirement Satisfaction Principle

5.1 Decomposition analysis of the first level

First, as the entity system, production system corresponds to the manufacturing as well as other related functions such as environment protection. Only the manufacturing function is studied here.

Second, realization of products manufacturing function also corresponds to supports of several principles, for example, related manufacturing technology principle, economic and management principle support, etc. In our case study, we only probe the manufacturing functions in the production system supported by demand satisfaction principle, the realization function of manufacturing products in productive system.

Third, demand satisfaction principle corresponds to several expressions: such as products' quality demand, products varieties demand, products' cost demand; products service demand, products response demand, and products quantity

demand. So, the above demands can be understood as realization of demand satisfaction principle.

Fourth, each demand satisfaction method corresponds to certain sub modular of production system, for example, time satisfaction method corresponds to speed responding production modular, and quality satisfaction corresponds to production modular of quality benefits.

5.2 Decomposition briefing of the second level

According to decomposition in 5.1, the five demand satisfactions correspond to the entity system of five production sub modular, for example, quality results production modular, varieties production modular. speed responding production modular, service production modular, cost-yielding product sub modular etc(Modular in this level is the first level modular);obviously each production modular can be realized through the decomposition of the overall function. This paper decomposes mainly the speed responding product modular.

First, speed responding product modular corresponds to three realization functions: quick responding product function (for short quick correspondence), zero time responding product manufacturing function (abbreviated as zero time responding) and the usual responding function of manufacturing (abbreviated as usual corresponding).

Second, as the function realization of the next supporting principle to demand satisfaction principle, there are quick satisfaction demand principle, zero time satisfaction principle and the usual satisfaction principle, they support quick response, zero time response and the general response respectively..

Third, under the support of quick satisfaction realization principle, the productive methods of Mass Customization (MC) can be applied to realize quick response; we can also adopt the Customization Production (CP) to realize the usual response; under the support of zero time satisfaction principle, Mass Production and Instant Customization can realize respectively realization of zero time response.

Fourth, the quick response production modular can be constructed by MC production method (This modular is in the second level, the same in later discussion and thus omitted.), to realize quick respond to market requirement; CP method can construct Customization response production modular to realize the function of general market requirement; To construct I production modular by MP method construction or to construct II production modular by IC method construction can both realize the instant response market requirement.

Fifth, according to floor modular determination calculation process of enterprise system decomposition, MC Production method corresponds to quick responding production modular, the customization pattern production modular corresponding CP production corresponds is floor modular, the decomposition stops; While to the two production modular of instant response I and II

corresponding to zero time response function modular, the decomposition continues.

5.3 Decomposition analysis of the third level

First, to define instant response I production modular can provide the instant response function of finalized products, Instant response II production modular can offer innovative and customized instant response functions.

Second, as the zero time satisfaction principle's next supporting realization function, they are customization instant satisfaction, innovative productions instant satisfaction and personalized instant satisfaction principle respectively, they support the customization production instant response, innovative products instant response and customization instant response.

Third, under the support of customization instant satisfaction principle, the instant response function of pushing production method to realize the customization product can be applied; Under the support of innovative instant satisfaction principle, the pull method can also be adopted to realize the instant response of innovative products; Under the support of personalized product instant satisfaction principle, the pushing-pull combined method can be applied to realize the customized products instant response market requirement function.

Fourth, through pushing production method, the instant response production method can be constructed(this model is divided into three levels, the same in later discussion and thus omitted),to realize customized product instant response to market requirement; the push-pull combination production method can construct the personalized product instant response production modular and fulfill the personalized product instant response market requirement;

As function modular corresponds one to one with the entity modular, the decomposition process of the whole production system ends. Function modularity by customer demand satisfaction principle of the final production system is: quick response market requirement modular, general response market requirement modular(modular in the second level), customized product instant response market requirement modular, innovative product instant market requirement modular and personalized product instant market requirement(sub modular in the third level).

The sub modular of production system decompositions are quick response production modular and the general production modular(sub level in the second level), customized product instant response production modular, innovative product instant response production modular and personalized product instant production modular(sub modular in the third level).

6 Conclusions

Through the application analysis of modularization theory this paper puts forward the function-principle- method-entity decomposition system of enterprise

modularization, studies the floor function and the calculating process of entity modularity determination. It conducts simple analysis to modularization decomposition based on demand satisfaction principle and provides the preliminary researches for further enterprise system construction through modularity integration.

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