Modelling in innovative design using systems engineering

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MODELLING IN INNOVATIVE DESIGN USING SYSTEMS ENGINEERING

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ABSTRACT: *Due to new challenges of market, companies increasingly expect to offer innovative products and improve the ability of innovative design. Innovative design is high interactive social process in which product, organization and knowledge are interrelated. The increasing numbers of internal components, as well as the relationships within each dimension and across dimensions, cause the complexity of innovative design. In order to managing uncertainty caused by complexity, we develop the descriptive models and the management model of innovative design by utilizing system engineering.*

KEYWORDS: *innovative design, complexity, systems engineering, descriptive model, management model*

1 INTRODUCTION

An increased focus on product design is evident to varying degrees in industry (Luchs and Swan, 2011) .Within industry, some argued that product design plays a key role in developing brands(Brunner et al., 2008). Others argued that, "design is one of the primary idea generators for the creation of viable business platforms" (Best, 2008). In short, product design is increasing recognized by managers as a strategy tool to be responsible the success of firms. However, new challenges, including technical advances, intensive customer needs, increasing diversification of the market and increasing world competition, may threaten the strategic position of companies. Thus, these challenges require that companies should contribute to innovative design, in order to get sustainable source of competitive advantage.

Development of complex products is high interactive social process involving hundreds of people designing interrelated components and making coupled decisions(Eppinger and Salminen, 2001). Innovative design as the key process of product development, it could be also considered as a complex social phenomenon. Thus, a project of innovative design is dynamic one in which product, organization and process are interrelated, and information is flowing back and forth between them (Danilovic and Browning, 2007). Additionally, that knowledge is a key component of all forms of innovation, especially in continuous innovation, is widely accepted (Chapman and Magnusson, 2006). Therefore, the knowledge dimension should be also considered into a project of innovative design.

As for innovative design, besides these higher expectations for innovation, companies also focus on the efficiency of the process. Therefore, the problem of mangers is to find the appropriate way to organize people and assign work over time, enable communication, and synchronize actions(Danilovic and Browning, 2007). Moreover, innovative design needs a framework which can balance innovation and control for companies. Nevertheless, the complexity, caused by the dimensions product, organization, process and knowledge, increases the uncertainty and risk of innovative design. Therefore, the crucial issue is to understand and explore not only the structures and information flow within each dimension, but also the interdependencies and relations across dimensions.

This paper has two key objectives. The first is to develop a series of descriptive models for describing the structures and the relationships between these dimensions by using UML language. There are vast literatures on the modeling of product(e.g.,Srinivasan,et.al., 1997; Krishnan and Ulrich, 2001) , organization(e.g., Moorman and Miner, 1997; Hobday, 2000) , process(e.g., Sterman, 2000; Browning et al., 2007) and knowledge (e.g., Chapman and Magnusson, 2006; Berends et al., 2007; Xu et al., 2010). In developing these descriptive models, our purpose is not to dismiss the importance of

existing models, but pay more attention to strengthen the relationships between these four dimensions in innovative design. In this paper, we adopt the modeling language and standard of systems engineering to develop.

The second objective is build management model for balance between control and innovation. With reference to engineering design, the design models in a systematic way have been developed. These traditional, linear models portray the design process as a recommended sequence of activities(Ulrich and Eppinger, 1995; Pahl and Beitz, 1996). On the one hand, these representations can offer designers a series of tools and methods to plan and optimize the design process. However, these design models raise the question as to what extent they foster or hamper innovation. On the other hand, creativity, as an integral and essential part of innovation, also attracts increasing interest in design research (Dorst, 2004). Therefore, in this study, we propose the management model based on V-cycle model of systems engineering, which provide us with a structured process at project level for control and a flexible process at a working level for innovation.

2 NATURE AND SCOPE OF INNOVATIVE DESIGN

2.1 Definition

Looking at Gero and Evbuomwan's definition of innovative design(Gero, 1990; Evbuomwan et al., 1996), one could define it with deign variables and forms, which still not go beyond the known framework. Le Masson et al. consider that innovative design tries to break away from the existing rules and to generate new rules (Le Masson et al., 2010). The former just classes innovative design into one of design categories from variable and form, and do not view innovation as the core part of it. The latter enlarges the scope of innovative design, and refers to a new form of design concerning traditional design function and new actors. However, a new form of design involves not only product, but also organization and process. At the point, three characteristics are required in innovative design:

(1) *Novelty*. The result of innovative design is different from all previously existing products.
(2) *Value*. The value of innovative design is related to human purpose, and should be judged by the customer and society.
(3) *Commercialization*. Innovative design is distinguished from the term creative design, because it involves commercial transaction.

We define innovative design, then, as some kind of process that applies the creative ideas or creatively applies the existing ideas to create a product, process or service for a customer and market. An innovative design should break away from the existing forms, and demonstrate these three characteristics above.

2.2 Scope of innovative design

In literatures, we can see that innovative design is a number of items interconnected by a multitude of relations. Negele identified product system, process system, agent system and goal system in a project or program (Negele et al., 1997). Browning argued that a project contains at least five domains: product, process, organization, tool and goal (Browning et al., 2006). However, most of researchers focused largely on the product, process and organization dimensions with little attention paid to the knowledge dimension. The knowledge is considered as a sustainable source of competitive advantage (Gopalakrishnan and Bierly, 2001). Therefore, it is necessary to understand a wider scope of innovative design, i.e., product, process, organization and knowledge.

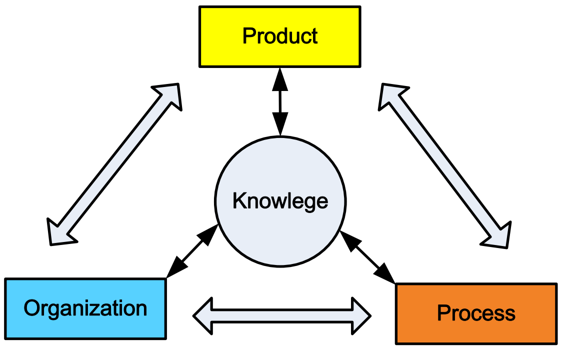

Figure1 the four dimensions of innovative design

Figure 1 describes the four dimensions and the relationships between them. Product to be designed is the desired result of the project, which can be decomposed into a series of designed physical components (hardware, software, and/or people). These components may be related via a variety of types and degrees of interactions. A process consists of related phases or subprocesses, and these in turn may be further decomposed into design tasks and activities. A design organization consists of people assigned to design the product, i.e., individuals, groups, teams, or other organizational unites.

Product, organization and process relate to each other as shown in Figure 1. In literatures of product development , the relationships between the three dimensions are discussed and explored, which helps to analyze the causes of process-related and organizational failures to efficiently design product(Bonjour, 2008; Browning et al., 2006; Eppinger and Salminen, 2001; Nightingale, 2000). Similarly, the understanding of these relationships could improve our understanding of and ability to work with innovative design.

First, the product to be designed influences the design organization, because organizational elements are re-

sponsible the design specifications of product components. Conversely, the existing design organization constrains the product to be designed in terms of alternative design solution. Second, there exists a relationship between product and design process. According to the product architecture, a series of design activities, tasks and phrase are organized. Especially for innovative product architecture, it requires more flexible organization structure. Conversely, the established design processes should be taken account into the design of unprecedented product. Because the established and matured design process provides a relatively stable and optimized process, it could help reduce the uncertainty of innovative alternatives. Third, the design organization is related to the design process. Innovative design is by necessity compulsory teamwork, and these design tasks are carried out in a parallel fashion (Zhang et al., 2012). Thus, the organizational elements need integration to some degree in order to finish these coupled tasks.

In the project of innovative design, the designer performs a series of design activities in order to get new, even creative results. Consequently, innovation is the result of the design. In order to stir up more innovation, it should integrate different knowledge area during innovation process (Fiol, 1996). As for the innovation of innovative design, it involves not only the product, but also organization and process (Zhang et al., 2011). Product innovations are outputs that are introduced for the benefit of customers, while organization innovations and process innovations pertain to organizational and process structures that mediate between inputs and outputs(Gopalakrishnan and Bierly, 2001). Therefore, the exploitation of knowledge is carried out not only in the internal interactions of the product, process and organization dimension, but also the relationships between the three dimensions. Additionally, innovations in these dimensions cause the exploration of knowledge.

2.3 Critical dimensions of the complexity of innovative design

According to the analysis above, the scope of innovative design involves the product, process, organization and knowledge. Eppinger and Salminen (2001) and Bonjour(2008) respectively analyzed the complexity of product development from product, process and organization. Additionally, the intrinsic uncertainty and breadth of the knowledge increase the complexity. Therefore, complexity in innovative design not only stems from the three domains, but also the knowledge involved. In this section, according the characteristics of innovative design, we analyze the complexity from the four dimensions. The four dimensions can all intact with each other, and produce a continuum of complex project.

2.3.1 Product

In the background of innovation, the product to be designed may be complex in its functions, forms, architectures, and integration.

(1) Function and form

In terms of the sources of innovation, the increasing number of the new functional requirements requires many layers of decomposition of product, which leads to be more complicated for design. Moreover, consumers engage with the integrated product and not just its form nor just its function (Luchs and Swan, 2011). The new forms of product are also the determine factor of innovative design. In other words, innovative design should address both form and function as integrated elements. However, when form and function are addressed simultaneously it is usually at the expense of one element over the other (Dahl, 2011).

(2) Product architecture

Product architecture is defined by not only these elemental components, but also the interactions between these components. If there is creative output at the architecture level of product, it could be considered as one of the types of innovative design (Howard et al., 2008). While making decisions about the ways in which components are integrated together to form a coherent whole, it requires knowledge about these component's core concepts, the way in which these components are integrated and linked each other(Hobday, 1998). The quantity of possible creative alternative product architectures can greatly raise coordination problem for designers, especially for an original alternative. In addition, the larger the number of components, the more difficult the decision choices would be (technology, the technology chosen).

2.3.2 Process

The result of an innovative design should include elements of originality with respect to competitors; then the process should be innovative. However, innovation cannot be a priori coded and modeled. Meanwhile, the dynamics and uncertainties of this process raise the difficulty of management.

(1) Iterations and feedback

In practice, innovation is a coupling and matching process. To validate the effectiveness of innovative process, there may be substantial iteration or feedback loops from later to earlier design stages. On the one hand, any iterations and feedback in innovative process effect components and subsystems that are vertically or horizontally related (Nightingale, 2000). On the other hand, when the components are systematically related across subsystems and the specifications of components are impossible to match or incorrect, the redesign activities occur. An excess of redesigns takes time to settle down into stable design configuration and add to the cost of design.

(2) Dynamic of design problems

In the sense of the problem structure, innovative design

is more to an evolving process between the design problem and the corresponding design solution (Dorst and Cross, 2001). So it is difficult to clarify design problems at the beginning of design. Meanwhile, these "emergent properties", such as changes in customer requirements, changes in regulations and environments, would add to the complexity of innovative design.

(3) Creativity
Creativity, comparing the various definitions of innovation, is often seen as the essence of innovation (Von Stamm, 2008). It is not simply concerned with the introduction of something new into a design. Rather, the introduction of "something new" should lead to a result that is unexpected and valuable (Gero, 1996). More precisely, it needs to go beyond the known framework, including design variables and design forms (Zhang et al., 2012). Despite the advances in understanding of creativity, we still cannot accurately prescribe a comprehensive mechanism for creativity. So the creativity involved causes the unpredictability and risks of innovative design.

2.3.3 Organization

As for the design of innovative product, especially for complex product, it is impossible to finish the tasks we requested of each individual. Innovative design is therefore by necessity compulsory teamwork, and different team members need an organization form to perform design tasks. The elements of organization, such as organization structure and communication way, influence the efficiency of innovative design.

(1) Organization structure
Organization structure determines who works with whom and who reports to whom (Eppinger and Salminen, 2001). Design teams develop these components and subsystems of product, and work together to integrate all of these components to arrive the final product (Bonjour and Micaelli, 2010). Thus, the organization structure corresponds to the product architecture. With the increasing complexity of product architecture, it needs more flexible organization structure to integrate the product components. Moreover, changes and requirements of the possible creative product architectures require organization to synchronize actions and ensure the collaboration of designers. Consequently, the escalating coordination problems are one of the sources of complexity.

(2) Communication
Different design terms have different understandings of the same problem, especially for a new design problem, and thereby produce incompatible solutions (Nightingale, 2000). In order to reduce the type of uncertainty, it needs communication between different units by the means of communication. Meanwhile, openness and dynamic communication between designers, teams facilitates the acceptance of new perspectives and can stimulate innovation (Alves et al., 2007). Therefore, these communication problems caused by innovation make the whole project more complex.

2.2.1 Knowledge

Innovative design can be understood as the interplay between the space of concepts (C) and the space of knowledge (K) with structure and logics (Hatchuel and Weil, 2003). More precisely, it involves the pursuit of new field of knowledge, not only the utilization of the existing knowledge. The characteristic requires that the realization of innovative design has a different approach to knowledge than the realization of routine design (Xu, 2010). And the learning activities consist of the main activity of knowledge exploration.

However, knowledge and learning are subject to path dependencies (Garud and Karnøe, 2001). It means that future development strongly depend upon past developments. In practice, the relative, situated and tacit nature of knowledge make it more difficult to explore new knowledge (Berends et al., 2007). Further, because designers and companies tend to keep on doing the same in situations in which that is not effective anymore (Hill and Rothaermel, 2003), existing knowledge may inhibit the creation of new knowledge. Finally, companies lack the knowledge of the feasibility of new technologies, which causes the substantial uncertainty of innovative design. Consequently, the problem, how to carry out knowledge exploration so as to promote more innovation, increases the complexity of innovative design.

3 MODELING INNOVATIVE DESIGN

In general, complexity can be handled by using a systematic approach to gather, organize, integrate, and analyze. A model is an abstract representation of a reality that provides a basis for managing uncertainty caused by complexity (De Meyer et al., 2002). With reference to the complexity of innovative design above, it is also necessary to utilizing model to provide a comprehensive framework for innovative design. In the section, we will build the descriptive model and the management model of innovative design by utilizing the standards, methods and models of systems engineering, in order to explore the structures and relationships within each dimension and across dimensions.

3.1 Modeling basis: Systems engineering

Systems engineering, as an effective way to manage complexity and change, has been recognized as a preferred mechanism to establish agreement for the creation of products or services. The fundamental purposes of systems engineering are to guarantee that the system matches real needs through proper specification of demands, to predict the properties and behavior of the system, and to guarantee them through the design of an appropriate architecture(Meinadier, 1998). Additionally, it is also a cooperative and interdisciplinary process for solving problems that aims to ensure a proper compromise between system strategy and constraints (AFIS, 2010). Finally, Systems engineering has much wider concerns than addressing the product system, and also

encompasses social interaction and organizational systems. Therefore, systems engineering provides operational and management standards, methods and models for innovative design.

(1) Systems engineering standards
Since the 1990's, the number of the systems engineering standards has grown to guide developers to master the development of complex systems, such as IEEE 1200, ISO 15288, EIA 632. By identifying good practices, these systems engineering standards define the interdisciplinary tasks and processes that are required from transform stakeholder needs, requirements, and constraints to a system solution. The recommended processes described in the standards can be applied to the whole system life cycle including design, development, production, use, support and withdrawal. Meanwhile, they can be also applied in a concurrent, iterative or recursive way to a system and its components.

Compliance with the processes and recommendations in the standard enables, designers can develop feasible and cost-effective systems by defining a complete and consistent set of requirements. Besides, the systems can satisfy not only the nominal requirements with respect to cost, time and risk constraints, but also each stakeholder, etc.

(2) Systems Modeling Language
One of the goals of SE is to ensure the consistency and interoperability of these representations during the project. To do this, new models based on languages such as Systems Modeling Language (SysML) try to unify the representations of the system into a single model throughout its life cycle.

SysML is the result of joint initiative of OMG and the International Council on System Engineering (INCOSE). It is a general-purpose graphical modeling language for specifying, analyzing, designing and verifying complex systems that include hardware, software, information, personnel, procedures and facilities(OMG, 2006). In particular, the language provides graphical representations with a semantic foundation for modeling system requirements, behavior, structure, and parametric, which is used to integrate with other engineering analysis models.

(3) Systems engineering model
A system life cycle includes two phrases: the conceptual phrase, which is to evaluate new business opportunities and to develop initial system requirements and a feasible design solution; the development phrase, which is to design a system-of-interest so as to be implemented, integrated, verified and validated(Deniaud et al., 2011). Design teams are involved in the two phrases, which is that may be represented by the "V-cycle model", a top-down approach(specification and design) followed by a bottom-up one(integration and validation) (Bonjour and Micaelli, 2010). This model represents the design logic behind a complex system, including the mechanism of problem decompose and the mechanism of adjustment. These mechanisms enable refining of the definition of needs while evaluating the pertinence of proposed solutions.

In despite of involving something of an art, innovative design still has many consistent patterns. While innovative design seeks to design something innovative, the designer or the design team tends to follow a pattern. That is, the process of innovative design requires some repeatable structures. Therefore, the V-cycle model provides us with a reference to reduce the complexity.

3.2 System views

Since the system engineering perspective is based on system thinking (INCOSE, 2006), it is necessary to systematize the product, process and organization. Through the systematization, we can make better model innovative design to understand, define and work with systems. Before moving further, we need a better understanding of the relevant terms, i.e. "system", "product", "process" and "organization". A system is "a combination of interacting elements organized to achieve one more stated purposes" (INCOSE, 2006), or "a set or arrangement of elements that are related, and whose behaviour satisfies operational needs and provides for the life cycle sustainment of the products"(IEEE, 2005). In section 2.2, we can see that product, process and organization could be decomposed into a series of related elements (product: component; process: design activities or tasks; organization: work teams, groups or individual). Comparing these characteristics with the definition of system, we can conclude that product, process and organization are a kind of system.

3.3 Descriptive model of innovative design

The descriptive models we propose intend to represent the structures and relationships within each dimension and across dimensions of innovative design. Since we treat the product, process and organization as a kind of system, these models are presented by means of the unified modeling language (UML) class diagram. Figure 2 describe a general model of innovative design. The class "project" is composed by an ensemble of organization, process, product and knowledge. The class "organization" designs the class "product" by performing the class "process". The class "knowledge" is related to the others by the association "support". According to the general model, we will discuss respectively these classes in more details in the following sections.

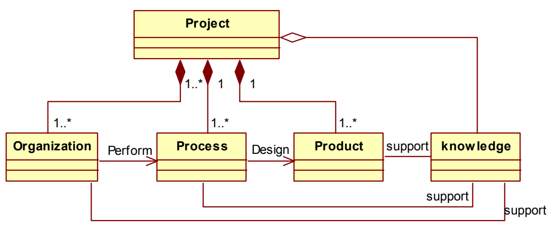

Figure 2 The general model of of innovative design

3.3.1 Descriptive model of product

In an entire project of innovative design, we consider the product class as the basic classe that relates other dimensions, as shown in figure 3.

(1) The class "product_model"

Since the product is the final result of innovative design, designers must determine the overall layout design (general arrangement o components), the preliminary design (the choice and arrangement of materials)(Pahl and Beitz, 1996). The class represents the physical form of the product, which is composed by a series of components (the class "component") and the relationships (the class "relation_component") between these components. The class component consists of the class "resource_material" and the class "topological_relation_material".

(2) The classes "product_funciton ", "product_behavior" and "product_strucuture "

John Gero proposed his FBS (Function-Behaviour-Structure) model of design as a theoretical base for understanding design (Gero, 1990). According to the three concepts of the FBS model, it is very useful in integrating the design process and the creative process and accords with the system view of innovative design (Zhang et al., 2012). Therefore, the innovative criterion (the class "criterion_innovation") of product is consisted by the classes "product_funciton", "product_behavior"and "product_strucuture". Finally, the clients (the class "criterion_innovation") judge whether or not the product satisfies the requirements and the level of innovation.

(3) The class "solution_technology_innovation"

The product is realized by one or plusieurs innovative technology solutions (The class "solution_technology_innovation"), that is production documents. The information of general arrangement, components and materials should be included in the class "solution_technology_innovation". Meanwhile, this class, as one of the elements of knowledge dimension, plays a link role with knowledge.

3.3.1 Descriptive model of organization

Designers depend on the results produced by others and others depend on their results. Only the coordinated activities of all designers will lead to a satisfactory overall result. In the descriptive model of organization (figure 4), we build the main concepts of design organization.

(1) The classes "department", "profession" and "outside units"

During the process of innovative design, a design team is formed by not only of members of the design and development department, but also those from other departments, even outside units. Therefore, as different forms of organization, the elements of the classes "department", "profession" and "outside units" form a design team.

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(2) The class "design project"

In contrast to the functional and matrix organization, the project-based organization (PBO) has been put forward as a form ideally suited for managing increasing product complexity, fast changing market, customer-focused innovation and market, and technological uncertainty(Hobday, 2000). Thus, the PBO becomes the main organization structure of innovative design. The class "design project" is composed by component design team, the system integration team, supplier's component design team. The division of work between different component design teams is determined by the class component of the product dimension. This team is led by a project manager (the class "manager"), works independently. Designers (the class "designer") are related to the class "task" of process dimension by the association "support".

(3) The class "design project structure"

This class can be also as the elements of knowledge dimension, which is consisted of the class "topological_relation_team", the class "topological_relation_designer" and the class "designer".

3.3.2 Descriptive model of process

A design process can be considered as a complex set of integrated efforts. An inappropriate design process not only affects the efficient of design phrases but also increases the possibility of failure. These design activities are classed into four phases: task clarification, conceptual design, embodiment design and detail design (Pahl and Beitz, 1996). It would appear, due to the frequent reference and use, which the traditional representations offer designers a useful tool to design.

Therefore, in the descriptive model of process(figure 5), the class "process" is composed of the class "design phrase", and the latter in turn may be further decomposed into the classes "design activity", "sequence_activity" and "relation_activity". Every design activity corresponds to one or plusieurs design task (the class "task"). Since a design process has to meet the project goals, the design tasks contribute to the requirements in product dimension. Moreover, the design tasks build the relationships between the process dimension and the organization dimension. In knowledge dimension, the process structure is composed of a continuum of the classes "design activity", "sequence_activity" and "relation_activity".

3.4 Management model of innovative design

In the duration of innovative design, innovation means that companies should apply the creative idea or creatively apply the existing idea into all possible product or service values. However, companies also confront the increasing uncertainty and complexity of innovative design, which has discussed in the Section 2.3. Therefore, companies need to control the process and predict accurately the outcome of these innovative activities.

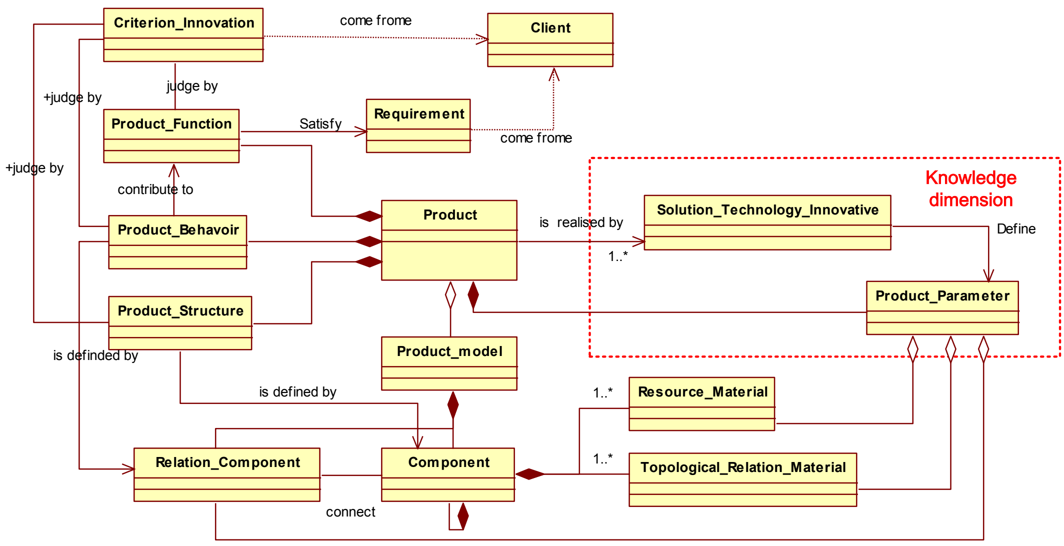

Figure 3 The descriptive model of product in innovative design

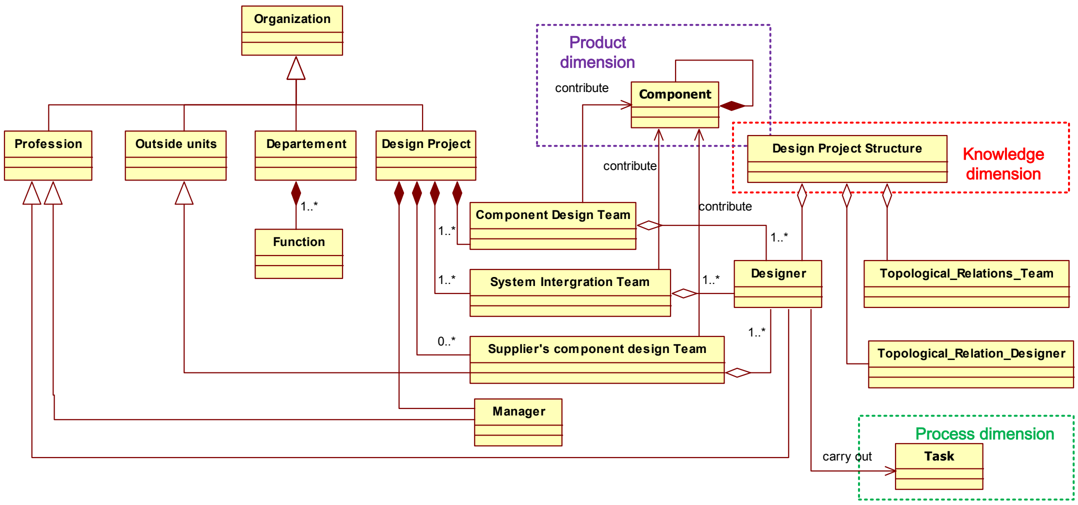

Figure 4 The descriptive model of organization in innovative design

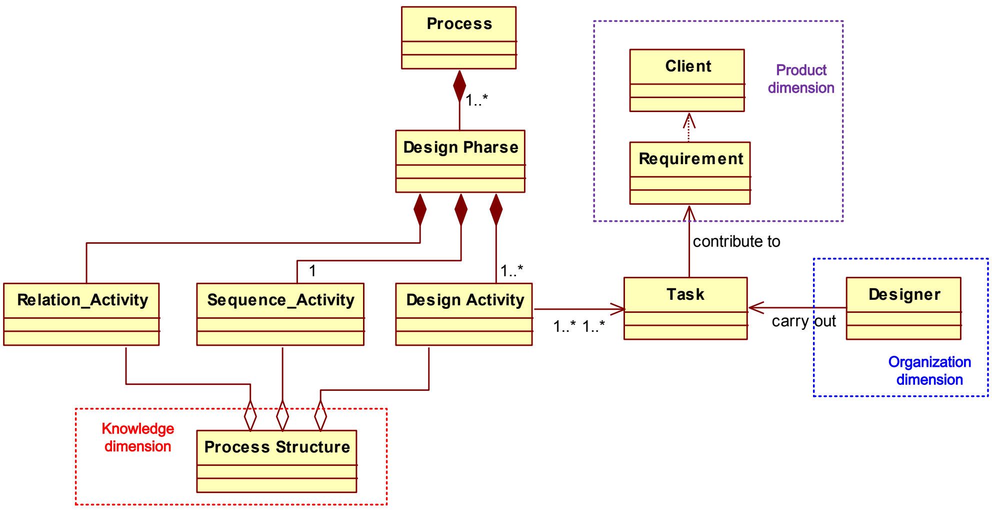

Figure 5 the descriptive model of process in innovative design

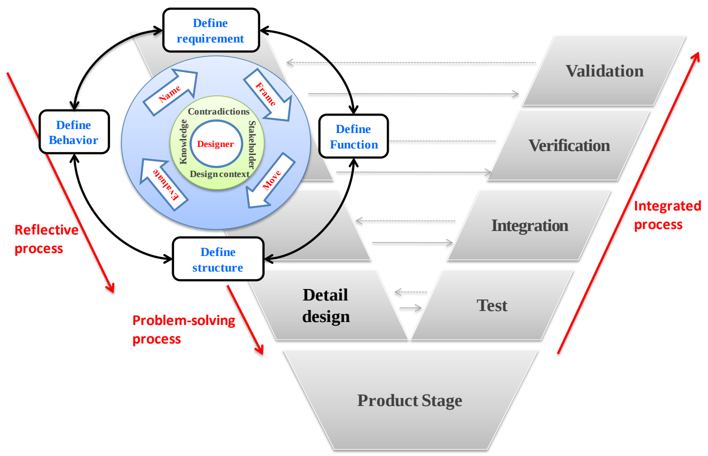

Figure 6 the management model of innovative design

That is, there is a need for finding a way of managing and organizing design so as to lead to systematic innovation. The expectation implies two means for innovative design:

- First of all, innovation is not considered as a natural, random phenomenon, but rather as a kind of impetus for design. That is, innovation is the essential and indivisible part of innovative design.
- Secondly, it is necessary to organize a series of programmed and systematic activities in order to generate innovation for companies.

To achieve the two goals, innovative design requires a balance between control and innovation, i.e., innovation in a structure. This involves determining the degree to which to apply a formal process (control) to innovative design, while allowing flexibility (innovation) to conduct work.

In the context of innovative design, control happens via utilization of structured processes. It involves a review at each level in the execution of the project to assess process status and determines necessary revisions. Looking at another aspect of the balance, namely innovation, it requires management flexibility for an organization or an individual. It captures the extent to which an organization or an individual is responsible for these work activities. So we developed a management model of innovative design in Figure 6.

As can be seen, the model shows the basic framework based on V-cycle model. This model is requirement-driven, and begins with task clarification. The main missions of the phase are to collect information about the initial confrontation of the design problem, and to define explicitly the design problem. These activities result in a "goal space" of design process in the form of a list of requirements. When these are understood and validated, they are placed under project control, and thus the system concept and the system specification are developed through conceptual design, embodiment design and detail design. In these phases, these innovative solutions are created by narrowing down the set of possibilities. Technical and economic constraints are used to guide the reduction. Because the number of possibilities is large, there are also evaluations and decisions which are used to guide the process and select a satisfactory solution. When the lowest level is defined, we move upward by the integrated process on the right leg of the V-model to ultimately arrive at the complete verified and validated system.

The circle part of this model is shown from the perspective of companies. The circle of arrows represents the main activities of the reflective practice, namely name, frame, move and evaluate. These activities depend on a two-way flow between the designer and influential factors, represented by the central disc. These factors include knowledge, stakeholder and design context and contradictions to overcome. In addition, a large arc of the cycle could be seen to describe the different aspects of design activities. These activities ("Define requirements", "Define Function", "Define structure", "Define behavior") are developed in a "continuous improvement" spiral. In our view, it is very important that the designer has the possibility to return constantly one of three other activities at the time of these first design activities

In this model, several existing models, such as the Deming Cycle (continuous improvement), the V-cycle and the FBS framework, are combined. One of the advantages of the model is short feedback loops between the activities located in the preliminary design (the conceptualization phase, the left part of V-cycle). Even if the realization time of these activities can be longer than the preceding models, it allows the design process to improve by checking uninterrupted coherence of the proposed solutions. As for another advantage, it provides a certain degree of autonomy and solving mechanism of contradictions for the designer. The designer can construct the design problem based on the perception of the situation, and search an innovative solution in wider scope. Simultaneously, it can also reduce time and costs in the design realization phase. There will be fewer corrections, modification and validations when

the product is to be finished (the development phase, the right part of V-cycle).

Therefore, we believe that control and innovation are different roles that complement each other. Control is achieved through the rational problem-solving process in the project level, which provides an overall review and control for the entire process and each level. Innovation is achieved by the reflective practices in the work level, which allows somewhat autonomy to get innovative work done and respond to emerging innovative opportunities.

4 CONCLUSION

In this paper, we first explore the definition of innovative design through discussing the relationship between design and innovation. Subsequently, the basic scope of innovative design is constructed, i.e., product, process, organization and knowledge. The four dimensions are interconnected by a multitude of relations. Then we analyzed the complexity of innovative design based on the basic scope. The four dimensions of the complexity can all intact with each other, and produce a continuum of complex project. Whilst acknowledging that the complexity of innovative design observed in practice is more chaotic than the current scope suggests, understanding the relationships and the complexity of the four dimensions can improve innovative design.

Systems engineering, as an effective way to manage complexity and change, provides operational and management standards, methods and models for innovative design. Therefore, we develop the descriptive model and the management model of innovative design by utilizing the standards, methods and models of systems engineering. The descriptive model reflects the structures and relationships within each dimension and across dimensions of innovative design. It is useful for managers to find the appropriate way to organize people and assign work over time, enable communication, and synchronize actions In addition, the management model help companies to better balance between control and innovation.

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