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PRODUCT ORIENTED ORGANIZATION OF PEOPLE TOWARD FOSTERING CAPABILITIES IN PRODUCT DESIGN

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Keywords: organizational structure design, capability modelling, multiple domain matrix, communication modelling

1. Introduction

1.1 Background

The emergence of new markets and new entries entail the most competitive circumstances ever for product design. Organizations that design and develop products are struggling to survive in such a competitive global market. New products released by them must have better functionalities and/or be less expensive than others. Therefore, innovation in product design and development is crucial.
However, because products have become increasingly complex, and the number of people involved in product development has increased, it becomes unrealistic to enhance innovation in all possible areas. In other words, companies need to strategically decide which parts and/or aspects of a product should be enhanced. Innovation without strategy may result in inefficient use of design 'capabilities' (designers' ability to work in the areas of their highest proficiency, e.g. fluid dynamics), resulting in failure in the market. This illustrates the necessity for strategically planned innovation.
To enhance innovations in product design strategically, companies try to foster capabilities. Because innovation is considered to be triggered by synergies among capabilities, enhancing communications among people who have different capabilities is seen as a prominent way to enhance innovation. Therefore, business planners are concerned about how to design these communications.
Organizational structure design is a fundamental method to realize these communications. That is, organizing people according to how communication is likely to happen is a primitive but long-lasting method to enhance necessary communications that strategically foster capabilities.

1.2 Objectives

The aim of this study is to deliberate how to structure an organization, which entails how to design communications in regular design works, in view of strategically fostering capabilities. Co-ordination of organizational structure defines how people work together, thus with whom people communicate. Therefore, the organization of people inevitably affects where and how people communicate. This paper proposes a support tool for co-ordination of organizational structure toward strategic innovation in view of communication among people.
Although there are many ways to design communications among people in a company, this paper limits its objectives to the co-ordination of organizational structure. Needless to mention, designing communications themselves (e.g. informal meetings) is one of the most prominent ways to enhance communications. However, changing the organizational structure implies fundamental changes as to how communications are enhanced in the regular design activities.

1.3 Approach

This paper proposes a decision support tool for co-ordination of organizational structure by analysing products and people who are involved in product design from the viewpoint of capability. In this paper, a product and organization are modelled in a computational form. By analysing the product model, organization of people is determined from a holistic viewpoint. In addition, analyses of the organization model show possible pitfalls in an organization from a focal viewpoint.

Communications are depicted in two forms. On the one hand, communications are seen as something required to fulfil the need to synthesize different capabilities. If a company wants to synthesize capabilities, people who have these capabilities need to communicate with each other. On the other hand, communications are something prescribed by the organizational structure. If people are placed in the same unit, it is quite natural for there to be communications among them. Relationships among capabilities are also depicted in two forms. On the one hand, the need for synthesizing capabilities is defined by products. On the other hand, the likelihood of synthesizing capabilities is seen as a result of communications among people. Therefore, the need for synthesizing capabilities, and thus, the need for communications are deduced from the product model. Subsequently, this leads to the co-ordination of organizational structure. In contrast, the existence of communications, and thus, the likelihood of synthesizing capabilities, is deduced from the organizational structure model. Consequently, it is possible to detect gaps between the communication required by products and the existing capabilities of the personnel.

To describe and analyse a model, Multiple Domain Matrix (MDM) [Maurer and Lindemann 2007] is employed. As the perspective to co-ordinate organizational structure is limited to capabilities, excessively detailed modelling and analysis on the limited perspective may lead to a misunderstanding of the result. Furthermore, given the difficulty of correcting data, appropriate abstractedness needs to be considered. Therefore, MDM and structural analyses can be considered to fit the purpose.

1.4 Position of this paper

The authors have proposed supportive methods for co-ordinating the design/development process in terms of ease of management by structural analyses of a product to be designed [Oizumi et al. 2011(1)]. Oizumi et al. suggested changing the design process to better manage product design, which is a rather temporal adjustment of ‘how we design’. However, fundamental changes in organizational structure are required for lasting adaptation. To complement this problem, the present paper proposes a method to co-ordinate organizational structure in view of fostering capabilities. And it rather focuses on a ‘fostering’ perspective on capabilities, whereas Oizumi et al. focused on an ‘utilisation’ perspective.

There have been several proposed models for organization design [Stanford 2007]. Although most of them are qualitative models [Romanelli and Tushman 1994], some of them discuss the relationship between process (in this case, not only the design process but also the broader business process) and organization in view of capability [Galbraith 1974]. Romanelli & Tushman proved the necessity for fundamental changes in an organization as a way to compete under environmental changes through empirical tests. [Tulskie and Bagchi 2001] proposed an integrated network model of a company’s resources, capabilities, and strategic position, which they called Strategic Capability Networks (SCN). In SCN, capability is depicted as a connection between resources and strategic position (or value proposition). On the basis of SCN, it is possible to analyse quantitatively how to invest on resources in terms of strategic position and how much investment on a certain resource is effective.

Deduction of organizational design by means of a computational model has been proposed [Kreimeyer et al. 2007], [Elezi et al. 2011]. Kreimeyer discussed the composition of integrated design teams of the simulation department and the embodiment design department from a capability point of view. Elezi discussed the structure of organizational units on the basis of the information transactions among them.

[Sosa et al. 2004] discussed misalignment of product architecture and organizational structure by comparing the Dependency Structure Matrix (DSM) of the design interface and team interaction. The observed misalignments provide managers with insights into which team interactions should be enhanced.

The present paper discusses organizational structure design by means of computational and descriptive models of a product and an organization. Though the perspective is limited to capability, it is possible to discuss the design of organizational structure in detail by the elicitation of capabilities. While Sosa et al. discussed misalignment of product architecture and organizational structure by comparing different domains (component and team), which is applicable where the organization is structured in view of product architecture, the present paper proposes gap analysis (see Section 4) to assess this misalignment in the same domains (design parameter, capability, and people). Thus, upon consideration of organizational structure from non-product architecture viewpoints (e.g., function-oriented team composition), the proposed method can extend the opportunity to apply DSM-based diagnosis to organizational structure.

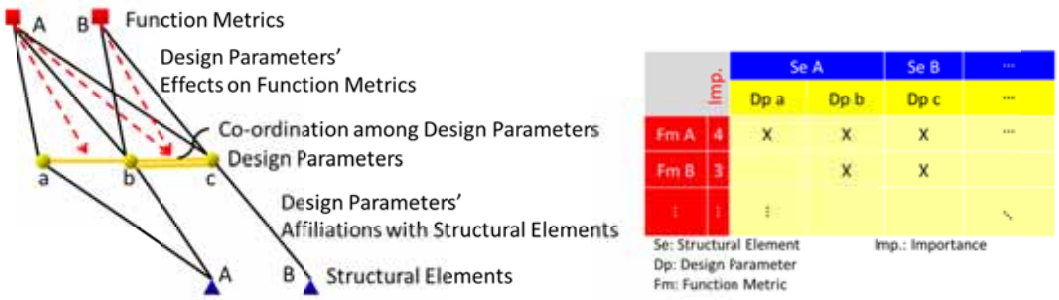
2. Product and organization models

2.1 Product model

In this study, a product is described by the combination of the following three domains (types of elements): design parameter, function metric, and structural element.

- Design parameter: Design parameters are specifications and characteristics of a product determined through design. There are effect relationships among design parameters. Thus, it is assumed that the determination of a design parameter should be done while considering its effect on other parameters.
- Function metric: Function metrics are observable metrics to measure the functionality of a product. It is assumed that these metrics are realized by determining the design parameters rather than by being directly designed. Comparative importance within a particular development project is assigned to each function metric. The alignment of function metrics and their weighting according to comparative importance reflect a company's strategy.
- Structural element: Structural elements are components of a product. A design parameter is affiliated with one of the structural elements. A structural element holds one or more design parameters.

These elements are interrelated. Relationships within the three domains in a product model are illustrated in Figure 1 (a).



(a) Network Description (b) Matrix Description

Figure 1. Product model

As shown in Figure 1 (a), relationships among elements entail their distinctive meanings. The relationship between a function metric and a design parameter depicts how a design parameter affects a function metric. Likewise, the relationship between a structural element and a design parameter depicts how a design parameter is affiliated with a structural element. Moreover, relationships among design parameters perform the central role in the analysis of a product model. When two design parameters both affect the same function metric, these parameters need to be co-ordinated for the achievement of the required level of the function metric. Therefore, the improvement in the design quality of a product depends on how well a company manages co-ordination among design parameters.

The proposed product model can be obtained by using a part of Quality Function Deployment (QFD) [Akao 1990], which depicts relationships among function metrics and design parameters. An example of QFD is shown in Figure 1 (b). The mapping between function metrics and design parameters in this model is nearly equivalent to the mapping between required qualities and quality characteristics in QFD. Because the proposed model makes use of QFD, which is widely known and used in reality to some extent, acquisition of data is rather easy. Though the need for co-ordinating design parameters is not directly described in the table, they can be deduced from the table by assessing how design parameters share function metrics. Furthermore, when relationships among function metrics and design parameters include more detailed descriptions (e.g., sensitivities, characteristics, etc.), needs for co-ordinating design parameters are enriched as well [Oizumi et al. 2011(2)].

2.2 Organization model

In this study, an organization is described by the combination of the following three domains (types of elements): capability, design resource, and organizational unit.

- Capability: Capabilities are abilities to implement design. Capabilities of an organizational unit are expressed as collective capabilities of design resources that belong to the unit. How a company co-ordinate capabilities shows its strategy.
- Design resource: Design resources implement the design. Each design resource belongs to one or several organizational units. Communications among design resources within an organizational unit are seen as enablers of co-ordinating capabilities.
- Organizational unit: Organizational units comprise design resources under certain objectives. This paper mainly discusses an organizational unit as a place to co-ordinate, and thus foster capabilities.

These three elements are interrelated. Relationships within the three domains in an organization model are illustrated in Figure 2 (a).

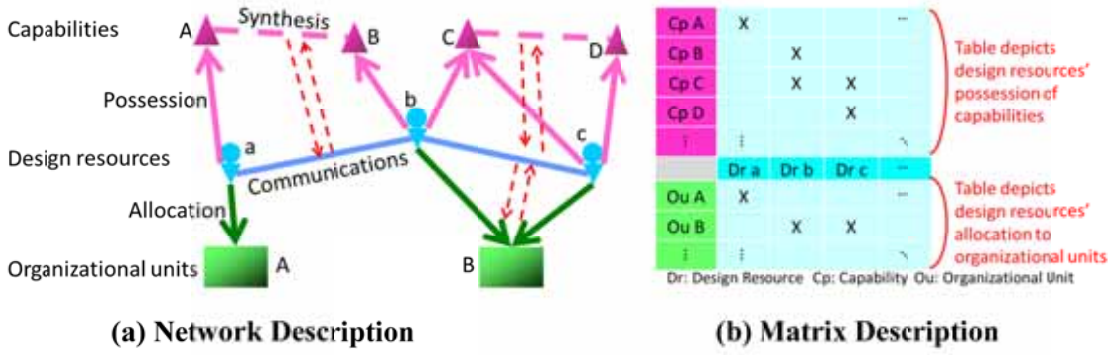


Figure 2. Organization model

As shown in Figure 2 (a), in an organization model, relationships among elements entail their distinctive meanings. A relationship between a capability and a design resource depicts how a design resource possesses a capability. Likewise, a relationship between an organizational unit and a design resource depicts how a design resource is allocated to an organizational unit. Relationships among capabilities depict syntheses among capabilities. In addition, relationships among design resources depict communications among design resources. Where synthesis among capabilities is needed, the existence of corresponding communications is required. In contrast, where communication exists, syntheses among capabilities are likely to happen. Moreover, where communication is required, those who are to communicate should be allocated to the same organizational unit. Likewise, where an organizational unit exists, design resources allocated to it communicate with each other. Therefore, how a company co-ordinates its organizational structure prescribes where syntheses among capabilities are likely to happen.

The proposed organization model can be obtained in QFD-like tables as well. This requires two tables: one to depict relationships among design resources and capabilities, and another to depict design resources and organization units. Examples of input tables are shown in Figure 2 (b).

The former table depicts relationships among design resources and capabilities as something that can be obtained from advanced human resource management systems (e.g. a human resources database), provided that the system incorporates capabilities in the form of an inter-company certificate or the like. Furthermore, the latter table, which depicts relationships among design resources and organizational units, is exactly the same as human resource allocation. Therefore, acquisition of data is rather easy as long as capabilities are explicitly managed as data in any form. Though communications among design resources and syntheses among capabilities are not directly described in the tables, they can be deduced from the tables by assessing how design resources share organizational units and how design resources communicate with each other, respectively.

2.3 Integration of product and organization model

Because a design team is co-ordinated for the purpose of designing products, it is quite easy to assume that the characteristics of an organization are related with the characteristics of the products it designs. An organization is a subject of design, while a product is an object of design. Thus, what connects an organization to a product is design. In the proposed model, a product model comprises design parameters that are determined through the design process, while an organization model comprises capabilities that constitute the ability to implement the design. Therefore, by linking design parameters and capabilities as shown in Figure 3 (a), a product model and an organization model can be integrated. Then, it is possible to discuss product-oriented co-ordination of an organizational structure.

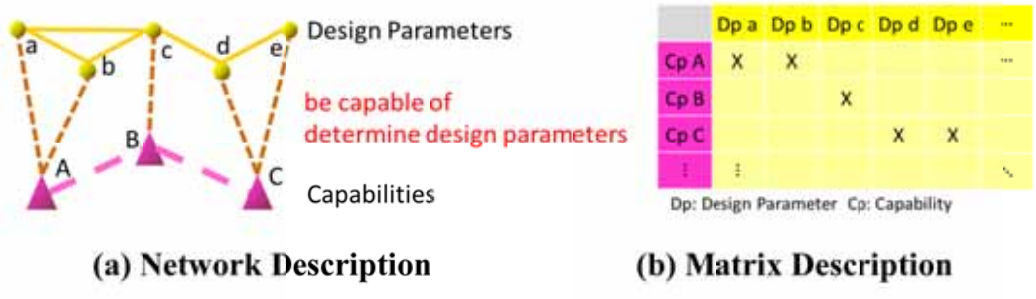


Figure 3. Relationships among design parameters and capabilities

To link design parameters and capabilities as shown in Figure 3 (a), a QFD-like table shown in Figure 3 (b) is required. A key to obtaining a relevant model lies in how well design parameters and capabilities are linked; therefore, adjusting the abstractedness of these two types of elements is quite important. It can be said that the abstractedness of capabilities tends to be higher than that of the design parameters. However, if the abstractedness of capabilities is far beyond that of the design parameters, this difference in capabilities becomes difficult to explain through products. Consequently, it may make analyses irrelevant. In such a case, capabilities need to be redefined with less abstractedness. This means the organization model also needs to be redefined.

3. Computational co-ordination of organizational structure

In consideration of organizational structure, it is important to align design resources in such a way that needed communications, and thus syntheses among capabilities, are likely to happen. However, as many design resources have a variety of capabilities and multiplicity (or redundancy), it is quite difficult for managers to consider all possible candidates for the ways to organize them without any bias, which is embodied in those managers from their experience with the past several projects. Though such bias can be effective and proven by past experience, applying past experience may result in misalignment of capabilities when a design project comprises new technologies, new strategies, or a new structure. To avoid this pitfall, it is important to consider all possible candidates for organizational structure. This paper suggests a computational method to logically deduce (free from bias) the organizational structure.

Here, communications are seen as something required to fulfil the need for synthesizing different capabilities. If a company wants to synthesize capabilities, design resources that possess those

capabilities need to communicate with each other. If design resources are placed in the same unit, it is quite natural that there should be communication among them. Therefore, it is possible to suggest how design resources should be allocated to an organizational unit on the basis of a product model.
The sequence of the method is as follows.

1. Deduce needs for synthesising capabilities from a product model (Section 3.1.)
2. Deduce needs for communications among design resources from needs for synthesising capabilities (Section 3.2.)
3. Group people into several candidate organizational units (Section 3.3.)

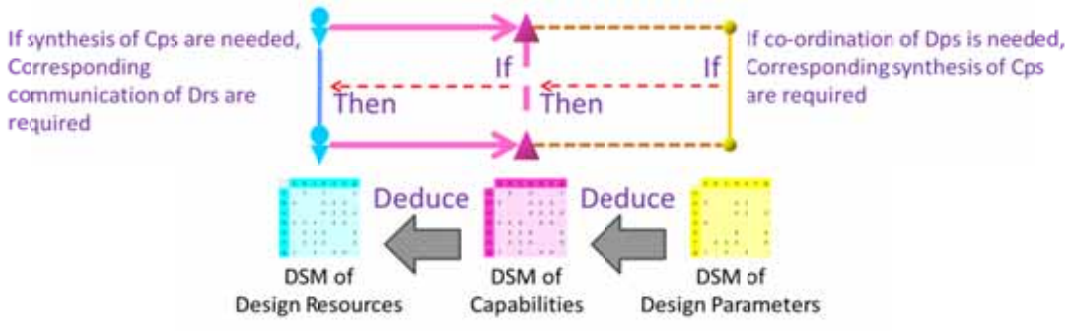


Figure 4. Deduction of needs for synthesizing capabilities and communication among design resources

3.1 Deduction of needs for synthesising capabilities

In this paper, it is assumed that capabilities are required to be synthesized where co-ordination among design parameters is needed, as shown in the right part of Figure 4.

3.2 Deduction of needs for communications among design resources

Likewise, it is assumed that design resources are required to be communicated where synthesis among capabilities is needed, as shown in the left part of Figure 4.

3.3 Grouping of design resources

Now that the needs for communications among design resources are recognized, by employing grouping algorithms of DSM, it is possible to find groups of design resources whose members should have frequent and intensive communications, thus suggesting possible sets of organizational units. However, because a DSM of design resources could be obtained through the procedure explained above, it would tend to be very dense. Thus, it would be better to apply thresholds to cut off weak relationships among design resources by tracing back to the reasons for requiring communications. The information that results in the need for communications is described in Figure 5.

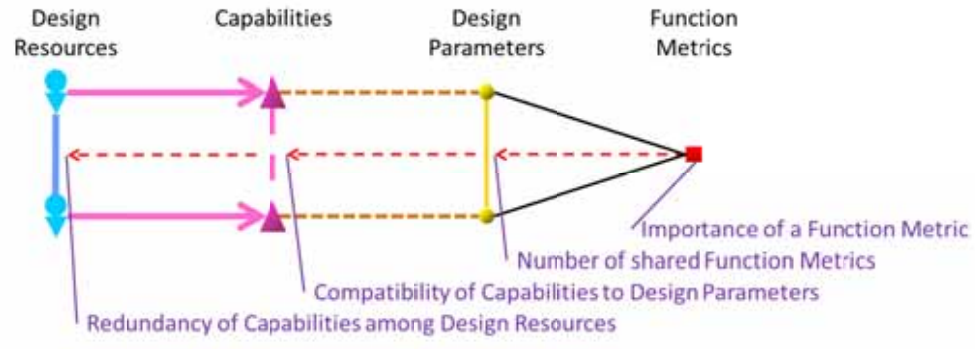


Figure 5. Information influencing strength of needs for communication

As illustrated by Figure 5, there are several sets of information that influence how strongly communication is required. By applying logical thresholds to those sets of information, a DSM of design resources becomes focused on respective viewpoints. There are four types of information items as follows:

- Importance of a function metric: Importance of a function metric defines the importance of co-ordination among design parameters. By focusing on important function metrics, the needs for communication among design resources are also emphasized.
- Number of shared function metrics: The more design parameters share function metrics, the more important it is to co-ordinate between those design parameters. Thus, by focusing on links between design parameters that share a large number of function metrics, it is possible to limit the needs for communication among design resources.
- Compatibility of capabilities with design parameters: When a capability is compatible with a large number of design parameters, it tends to be connected with many other capabilities. Therefore, focusing on more compatible capabilities implies focusing on the central issues of fostering capabilities, while focusing on less compatible capabilities implies considering subordinate issues that tend to be ignored.
- Redundancy of capabilities among design resources: If a capability is shared by many resources, it is a common capability that can be compensated for by others. In contrast, if a capability is held by a limited number of design resources, it becomes rather difficult to compensate. Therefore, there are strong needs for communication among design resources to synthesize those uncommon capabilities.

As for an algorithm to group design resources, the proposed method employs clique detection. Because the DSM of design resources tends to be quite dense, it is preferable to apply an algorithm that strictly limits the size and number of groups. For this purpose, clique detection seems to be appropriate, because it is a complete maximal graph comprising more than three elements, which means it is very strict.

A method to detect groups of design resources, which implies organizational units, is proposed above. However, there is no single correct way of applying thresholds. Thus, it is advisable to apply thresholds in a trial-and-error manner, as shown in Figure 6.

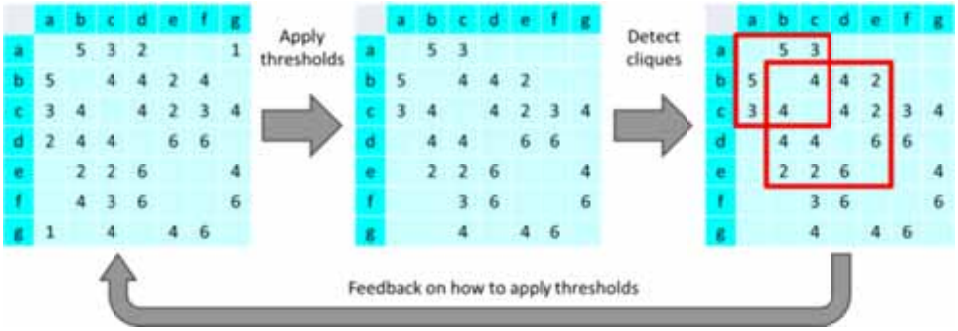


Figure 6. Detection of organizational unit

4. Visualization and analyses of management points on product and organization

In the previous section, a method for organizing design resources was explained. In contrast, this section explains how to visualize and analyse management points. When organizational units are already defined, it is possible to detect gaps between actual and ideal states of each domain. Figure 7 illustrates a comparison between the respective actual and ideal states of three domains (design resources, capabilities, and design parameters).

Here, ideal states are obtained from product models, as shown in Figure 5. Thus, relationships among elements in design resources, capabilities, and design parameters are 'required'. In contrast, the existence of organizational units defines communications among design resources, the existence of communications defines syntheses among capabilities, and the existence of syntheses defines co-

ordinations among design parameters. Therefore, it is possible to deduce 'existing' relationships in each domain.

By comparing 'existing' and 'required' relationships, it is possible to visualize and analyse points to be managed. This analysis, which is based on comparison between 'existing' and 'required' DSMs, is defined as gap analysis. If there are gaps between 'existing' and 'required' DSMs in each domain, difficulties can be detected. For instance, in the design parameter domain, while two specific design parameters must be co-ordinated, no realizing structure exists. Thus, gaps illustrate weaknesses in the organizational structure of a company. Likewise, consistencies between 'existing' and 'required' DSMs illustrate strengths of the organizational structure. To assess such gaps in detail, gap analysis not only shows differences in the form of existence or absence but also assesses the strength or weakness of 'existing' relationships by calculating weights of relationships.

If an organizational structure changes, certain factors subsequently change; these factors are 1) with who design resources communicate, 2) which capabilities are likely to synthesize with each other, and 3) how well the design parameters are co-ordinated. Therefore, it is possible to discuss the strengths and weaknesses of several candidate organizational structures through gap analysis.

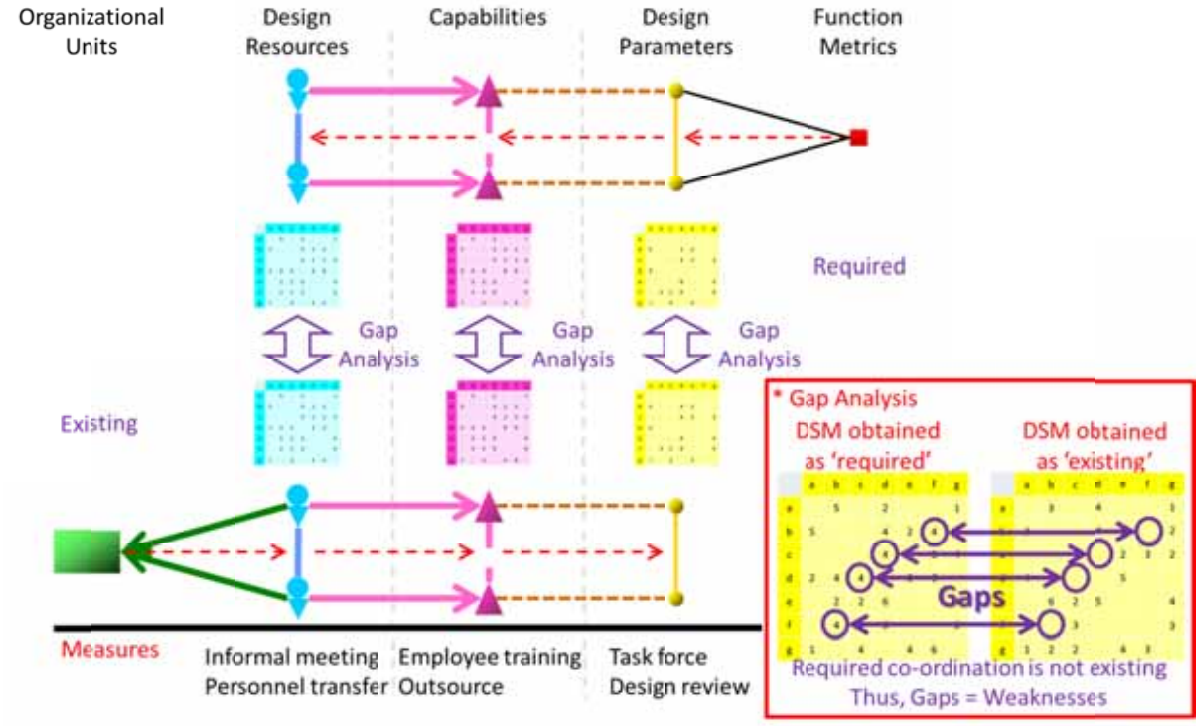


Figure 7. Gap analyses between actual and ideal states in three domains

Gap analysis can also be used for considering other improvements (not organizational structure changes) in an organization. In Figure 7, the measures written underneath each domain illustrate ways to improve the organization to fill the gaps in the three domains (design resources, capabilities, and design parameters). If there is a gap in the design parameter domain, the analysis shows that it would be rather difficult to co-ordinate design parameters. Therefore, gap analysis suggests organizing a task force or scheduling design reviews for the purpose of managing co-ordination in design processes. If there is a gap in the capability domain, gap analysis shows that synthesis should not be expected from these capabilities. Accordingly, effective measures could be training of employees or outsourcing of part of the design process related to those capabilities. If there is a gap in the design resource domain, the gap analysis shows that there is insufficient communication between design resources. Therefore, establishing a place and time for them to communicate their knowledge and insights would be an effective measure. Personnel transfer could also be an effective measure as it changes which people communicate with each other.

5. Verification example

To verify the applicability of the proposed method and the relevance of the result, this method has been applied to a pilot project in collaboration with an industrial partner. To manage and analyse data, the proposed method was implemented as a part of Design Orchestration Composer (DOC) software. Figure 8 shows screenshots of this application. Due to the confidentiality of the data, names of elements are anonymized. In addition, because a part of the required input data needed the permission of several departments, some of the data used for the project was edited.

As shown in Figure 8, by the proposed method, it was possible to find several candidates for organizational units through thresholds and the clique detection technique (Figure 8 (a)). By selecting several units and editing them, several candidates for organizational structures were found (Figure 8 (b)). If a different structure is considered, the manner in which co-ordination of design parameters is handled differs, as shown by the gap analysis (Figure 8 (c)). Different co-ordination strengths of design parameters imply a different company strategy. In Figure 8 (c), two different candidates for organizational structure were assessed by gap analysis. In these two matrices, red cells represent the absence of supportive organizational structure, pink cells represent rather weak co-ordination of design parameters, and white cells represent strengths. The result clearly shows that different organizational structures lead to different strengths and weaknesses. Based on the differences illustrated by the proposed method, managers can discuss which structure to use to implement their strategy.

As a result of this pilot project, it was confirmed that the proposed method can provide managers with an arena in which to discuss ways to co-ordinate organizational structure by showing different strengths in product design. Applicability of the proposed method was acknowledged by the industrial partner. Furthermore, the method shows logically convincing results. The project will continue to verify the proposed method and to explore further possibilities to extend it.

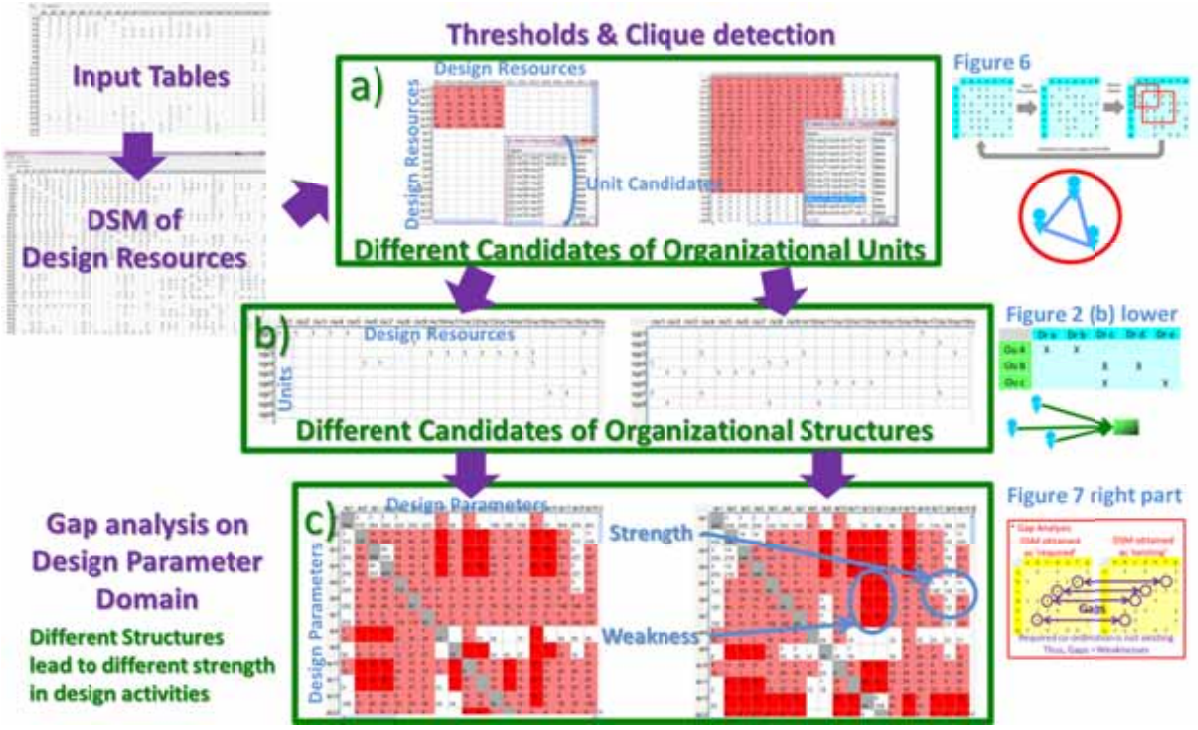


Figure 8. Screenshots of verification example

6. Discussion and conclusion

While [Elezi et al. 2011] discussed organizational structure on the basis of information transaction, the proposed method focuses on capabilities as connectors between people and products. Because the proposed method suggests an organizational structure based on the product it designs, it is possible to

discuss how to structure an organization by assessing how the strengths and weaknesses change when different structures are adopted. Though misalignment of product architecture and organizational structure were discussed by [Sosa et al. 2004], the proposed method can be used further for a wide variety of organizational structures. While [Sosa et al. 2004] discussed misalignment of product architecture and organizational structure by comparing different domains (component and team), which is applicable when an organization is structured in terms of product architecture, the proposed method assesses this misalignment within the same domains (design parameters, capabilities, and people). This is enabled by the elicitation of capabilities and connection of people and product by capabilities as bridges.

Capability has already been discussed as a perspective to structure organization [Galbraith 1974]. Galbraith discussed the relationship between capabilities and organizational structure in a theoretical and qualitative description. The proposed model extends the theory into a more quantitative form, which depicts relationships between capabilities and organizational structure as a matrix (or network) as done by [Tulskie and Bagchi 2001]. While the SCN proposed by Tulskie and Bagchi focuses on diagnosing organizational structure, the proposed method focuses on morphing of possible changes in organizational structure.

However, the existence of other perspectives on organizational structure, such as geography, corporate culture, politics, responsibilities, and decision rights, must be considered as suggested by [Stanford 2007].

Moreover, it usually takes a long time before the effects of restructuring appear. Thus, it is quite rare to restructure an organization merely for one generation of a single product. In most cases, companies restructure their organizations towards several generations of multiple products. By considering the gap between reality and the suggestion of the proposed method, the suggestion should be used rather as a diagnostic tool to detect difficulties in the design of a product and/or in an organization. Even if modelling of several generations of multiple products makes it possible to suggest a more relevant organizational structure, the actual implementation is quite difficult owing to the considerable effort required to collect data.

By considering differences in the time characteristics between a product and an organization, the proposed method is more suitable for matured products rather than those whose structures are comparatively stable over time. To apply this method to rapidly growing products, further abstraction of the product model should be considered.

In conclusion, this paper proposed an integrated model of a product and an organization. It leads to the following conclusions:

- The model enabled computational co-ordination of an organizational structure in view of its fostering capabilities.
- Analyses of gaps between required and existing relationships in the respective design parameter, capability, and design resource domains allow detection of difficulties. Thus, it is possible to discuss co-ordination of organizational structure in relation to capability and a product it designs.
- Gap analysis also suggests measures to improve the organization in terms of not only restructuring of the organization but also local improvements, such as design reviews.
- The proposed method considers capability as a clue to co-ordinate organizational structure. Incorporation of other perspectives, such as responsibilities and decision rights, may extend the proposed method and lead to more relevant co-ordination of organizational structure.
- Different time characteristics of products and the organization need to be considered.
- There might still be room for improved data acquisition, because it is burdensome for managers and designers to collect data.

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