POTENTIAL OF NATURE-INSPIRED APPROACH FOR ORGANISATION DESIGN IN PRODUCT-SERVICE SYSTEM

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Abstract

The importance of organisational properties in PSS development has been emphasised by previous research but the attempts to handle complex structure and communication network of PSS has been lacking. In this research, the potential of natural ecosystem as a source of inspiration for organization design in a PSS development was explored. The organisational problems in practice were investigated through the literature reviews and expert interviews with practitioners. In addition, the characteristics of natural ecosystem on different developmental stages were compared to those of systems in industry to identify the strengths of nature to be learned.
This study suggests that further studies involving sufficient cases of corporations and natural ecosystem are required to specify the relationships between artificial and natural systems and contribute to organisational improvement. Moreover, methodological approach to support practitioners to design organisational structures and communication strategies is necessary.

Keywords: Nature-inspired design, biomimetics, Product-service systems (PSS), Organisation Design

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1 INTRODUCTION

Product-Service System (PSS) is defined as a system to provide a mixture of products and services to satisfy customers' diverse and complicated needs. Compared to selling products, companies can provide tailored and customised offerings and maintain close relationships with their customers by adopting PSS. Moreover PSS strategy enables firms to save resources and energy so that they reduce the costs and run their business in more efficient way (Tukker and Tischner, 2006). Because of these advantages, many firms have adopted PSS as an alternative solution to overcome the limitations of their product-centred businesses. However, developing a successful PSS business model involves several intricate requirements to be fulfilled.

The organisational structure and communication are part of these requirements. Mont (2002) emphasises the significance of information management in a PSS for improving the communication among organisational members and customers. In a PSS, value is created by the interactions between service providers and customers so decisions relating to providing services are made on the downstream level. Besides, the collaboration among internal teams and different companies are enhanced. The author mentions that the interaction network between the stakeholders in and out of organisations can reflect these tendencies. In the research by Cook et al. (2006) the structure of a firm is introduced as an attribute affecting suitability for implementing PSS concepts. From case studies of the corporations that had transferred from manufacturing to PSS, they derived the findings that the companies have changed their structure from hierarchical to matrix network, which is more advantageous for providing customised and unique products and services. In a study to investigate organisational change in PSS business, Wallin et al. (2013) introduce key factors for successful organisational transition: business strategy and decision making, internal organisation structure, team composition and external networks and customer relationship. In addition, they discovered how the properties of organisations change according to different PSS types through case studies. The findings from these studies about the importance of organisational structure are in line with the previous studies which demonstrate that strategies on decision making and task distribution differ depending on the organisational structure (Herbst, 1976, Nelson, 1991). Some tools to depict the relationships and interactions among the stakeholders in a PSS have been proposed (Morelli, 2006) but further improvement is required to manage the complex structure and communication network of PSS.

Meanwhile, nature has been recognised as a rich source of inspiration to develop sustainable solutions throughout various fields of researchers and practitioners (Ball, 2001, Volstad and Boks, 2012, Benyus, 2012). Designers and engineers can start from problem definition to finding solutions from nature, or approach from accidental observation and discovery of nature phenomena. Cases and thoughts derived from nature are widely accessible regardless of industry and these are often known as Biomimicry, Biomimetic Design or Nature-inspired Design (NID). The prior attempts to get the clues to solve the problems from nature imply that nature can also be a rich source of ideas for PSS development.

Benyus (1997) identifies three levels of biomimicry approach from reductive to holistic view: form, process and ecosystem. Numerous biomimetic cases have been introduced through databases and previous studies. Furthermore, along with abundant attempts to apply natural principles to human artifacts, research on methodologies and design tools to support NID approach have been actively developed. Biomimicry DesignLens (Biomimicry Group, N.A.), BioTriz (Vincent and Mann, 2002), Natural Language Approach (Shu and Cheong 2014) and thesaurus for translation between engineering and biology terms (Nagel, 2014) are the representative examples of them. However, most of them are involved in product development using form or process level of biomimicry.

It does not mean that NID approach of the system level is an unexplored area. Some innovative attempts such as seeking inspiration from the cell membrane for designing a customer service system (Ayyadurai, 2011) or application of the evolutionary mechanism to build a digital ecosystem for online API management (Briscoe and De Wilde, 2006) have been made in academic field. Furthermore, an energy management system which was developed by the inspiration from communication of bees, is an example of successful biomimicry in practice (Watson, N.A.). A couple of biomimicry attempts for organisation design even have been made. Thompson (2008) introduces the strengths of teamwork in nature for the people who want to enhance the performance of their organisation. Furthermore, IDEO got some clues from the successful strategies in nature, and suggested the design solutions to improve the client's organisation (Fast Company, 2010). Even

though the several studies and application instances reveal the potential of NID approach in a system design, methodological studies on system level NID appear to be still far less compared to the other two levels. In detail, the issues on what aspects of nature can be applied to a PSS design to what extent, and which methods and tools would be effective need to be discussed on.
In this research, the potential of natural ecosystem as a source of inspiration for PSS development was explored. In order to respond to the research question of how NID approach can contribute to designing desirable organisational structure of a PSS, sub-questions were set as below:

1. What are the organisational problems in PSS companies?
2. How NID approach can contribute to resolving those problems?

To respond to the first questions, the organisational problems involved in adopting PSS were investigated through literature review and expert interviews (section 2). In addition, the characteristics of natural ecosystem on different developmental stages were compared to those of systems in industry to identify the strengths of nature to be learned (section 3). Finally the research questions were responded to based on the findings of this study (section 4).

2 CHALLENGES IN PSS IMPLEMENTATION

2.1 Literature review

The challenges of manufacturing companies to adopt PSS strategies have investigated by some preceding studies (Brax, 2005, Martinez et al., 2010, Lockett et al., 2011). When a manufacturing firm add service elements to their offerings, thorough information management and close communication among stakeholders become even more essential. However, their poor performance in managing and sharing information acts as a barrier to adoption of services.
The interaction problems are detected both from downstream and upstream of the systems. In the interaction between service providers and customers, the required information to provide services is split and discrepant so they have difficulty in providing consistent and high-quality services. In addition, their complicated and ineffective ways to communicate with customers and to collect information prevent them from improving service through feedback from customers. The hierarchical organisational structure in manufacturing companies is another obstacle; it gives the workers a misconceived perception that to communicate with customers is the role of particular teams, so reduce their motivation for active communication with and reaction to the customers. As for the interaction between firms, they usually have transactional relationships and avoid sharing information with external organisations for fear the leakage of their confidential information after the partnership breaks up. Lack of information sharing among cooperating firms weakens their mutual support and sometimes causes troubles in running businesses. These studies claim that information exchange is more likely to be smooth and close when the corporations have a relationship based on mutual consideration and trust.
As described above, previous studies provide valuable insights about the organisational problems in servitised manufacturing companies. However, the research to figure out the situations in productised service companies is scarce.

2.2 Expert interviews Methods

To investigate the problems related to organisational properties in PSS, expert interviews were conducted with the practitioners working in the Korean PSS companies. The information of the interviewees is displayed in Table 1. The interviewees were invited from both servitised manufacturing companies and productised service companies to investigate the diverse organisation patterns.
In the interviews following issues were mainly discussed:

1. What kind of structure and inter/intra-organisational relationships does the corporation have and how information flow and decision making occur?
2. What are the problems with current organisational properties in terms of adopting new service/product elements?
3. What are the obstacles to improve the organisational structure, relationships, information sharing and decision making?

The interviews were carried out for about an hour, recorded and transcribed. Afterward, interview data was segmented, coded and categorised regarding the relationships between the themes of segments (Galletta, 2013).

Table 1. Interviewee Information

	Interviewee A (Company A)	Interviewee B (Company B)	Interviewee C (Company C)	Interviewee D (Company D)
Type of business	Servitised manufacturing	Servitised manufacturing	Productised service	Productised service
Department	Marketing	Environment management	Marketing	Convergence business
Position	Managing director	Team manager	Senior manager	Senior manager
Years of service	16	9	7	10

2.3 Results

The findings from the interviews were organised to derive the responses to the interview questions. Also they were summarised in Table 2.

2.3.1 Organisational structure, relationships, information sharing and decision making of the corporation

Basically all the interviewees responded that their companies had hierarchical structures and took top-down approach for decision makings. In the hierarchical structure, the ideas which were generated in a working-level meeting were suggested to the managers so that they make decisions if the ideas were profitable or not. After the ideas were judged to be worth implementing, the managers gave instructions to the teams to carry out the projects. However, company B and C revealed distinguishing decision making process and team organisation respectively. Different from the other companies which develop products and services separately, company B handled product elements and service elements simultaneously. Interviewee B expressed the difficulty in developing PSS business model as follows: "As we should reach compromises about agendas related to both products and services, decision making takes longer time than ordinary product development process." Meanwhile, company C took a flexible team organisation strategy after a project is launched. While the departments of the other companies focus on the projects of their own business unit, company C did not have separate business unit and organised the teams for every new project. Interviewee C commented, “We do not have task force organisation formally, but our work approach is quite similar to the task force approach.”

In terms of inter-organisational relationship, the productised service companies were dependent on outside firms for product development and manufacturing. Interviewee C responded, “The internal organisation only determines developmental directions to identify development requirements and select final design, and product development is outsourced to external firms.” Since company D was not an expert on product development either, they also supplemented the shortage on their business through training workers, recruiting experts or outsourcing. They selected an appropriate strategy depending on if a function or a skill need to be internalised or not. In contrast, the servitised manufacturing companies took on both product and service development for themselves. Company B had a close relationship with the individual service providers. They worked under the control of the company, but had strong influence on it because the profits depended more on service provision than product sales. Therefore developers had close communication with service providers so that they can get feedback from users and improve their services immediately.

As for intra-organisational relationship and communication, the companies had distinct characteristics. Company A usually started from developing new products and added services subsequently due to the dominant position of engineers. He mentioned "While developing new hardware, new ideas about services, such as providing contents, are added as a market follower in the service sector…because development department is constructed as the major organisation of the company. Most of top management are also from development part, so we have constraints in making decisions about such

issues." Whereas, interviewee C reported that the responsibility and authority was quite dispersed in her company so the atmosphere of a team was heavily influenced by the team leader's attitude rather than the power of certain department.

2.3.2 Problems in current organisational properties

Two servitised manufacturing corporations displayed similar problems: gap and imbalanced power between different departments or teams. Although the workers in a company aimed at success of a project and increase of profits, they had different goals and key performance indicators (KPIs) depending on their department. That is, the goals and KPIs of a department could conflict with those of others so act as a barrier to close communication, active cooperation and efficient decision making between different departments.

Furthermore, strong influence of certain department on decision making prevented the organisation from developing creative business models and enhancing competitiveness of service elements. Especially in company A, engineers had stronger power than other departments so product specification and technical feasibility were addressed as the most important criteria for evaluation of ideas. Interviewee A stated "When we have a new idea, our organisation first consider if we can make the product or not, if it is technologically feasible or not because most of members are engineers. A majority of the members from the presidents to the employees has engineering mind." That was why the company concentrated on product elements and took passive approach in implementing service business. This tendency made them start service businesses behind other competitors' and they generally had lower possibility of success in the market.

Whereas, company C was suffering from the lack of information sharing and weak consensus between different teams and companies for the other reason. According to interviewee C, practitioners had difficulties in understanding the nature and the situations of other teams and partnering companies. Even though the teams and the companies were not in a competitive relationship nor keeping in check each other, they could not help overlooking detailed points to cover broad issues in a hurry. She also claimed that considerable amount of time was consumed to construct new project teams and select partner companies. Consequently, these problems disturbed the workers in investing enough time and efforts to improve the quality of their offerings.

Meanwhile, interviewee D expressed the problems related to the uncertainty and the unpredictability in a new business. As the members had little experience in the new area, they could not establish a reliable business plan based on enough data. Moreover, they faced an unexpected problem in their new business and it was much harder to overcome because they did not have a manual to handle it. Although the uncertainty itself was not an organisational problem, it made the company hesitate over adjusting organisational structure and making decisions.

2.3.3 Obstacles to overcoming the problems

The firms had made several attempts to change their organisational strategies and to overcome the organisational problems. Task force (TF) approach, establishing a team to carry out a project, was one of the alternatives of department-based structure for servitised manufacturing companies. If a project team consisted of the members from different department, they could handle a project from beginning to end intimately and make decisions by themselves. Interviewee B commented "From the company side the organisation was divided into several departments for work efficiency, but forming a project team also has advantages in raising performance. So we are changing our process into starting a project with a TF team and maintaining the business through department-based operation after it is launched and stabilised, but we still have difficulties with it." Interviewee A also responded that his company also had attempted several times to adopt TF approach but it had not been successful.

The interviewee A and B identified the obstacles to adopting new organisational strategies as large scale of organisation, past experience of failure, organisational culture and political issues. They perceived the gap between different departments as an inevitable consequence which emerges as an organisation gets larger. Although they understand that the flexibility of the organisation can be an advantage for their businesses, the managers avoid spending their time and effort to test alternative organisational strategies because of their experiences of failure. Interviewee A, who has experience of working at an overseas branch, commented that especially in Korea, vertical relationships are emphasised in a hierarchical structure, so conflict of interest and power struggles between different

departments lead to uncooperative attitude, uncomfortable mood for communication and failure of TF approach.
Whereas the interviewees from the productised service companies revealed different limitations in organisational improvement. The interviewee C suggested that the problems caused by their complicated organisational structure could be resolved through long-term cooperation. When a company or a team work with others for a long time and accumulate know-hows, the working environment can be stabilised and the quality of products and services can be improved. However, company C could not keep a cooperative relationship in its internal organisations; it constructed a new team for each project. In addition, it had a negative perception about the continuous partnership with a certain company as it could bring about adhesive corruption. Although the workers knew how to overcome the problems, they could not change it since it was a deep-rooted tendency.
Meanwhile, interviewee D mentioned that the uncertainty was inevitable for running a new business. According to his comment, a corporate have to keep developing new business models to raise profit continuously. When a new business item does not meet the external conditions such as government policy, business partner relationship and social situation, the unpredictable problems get more complicated.

Table 2. Summary of the interviews

	Organisational characteristics	Organisational problems	Obstacles to overcoming problems
Company A	Product centred development process led by engineers	Low competitiveness in service development caused by imbalanced power of engineers	Failure experience Organisational culture Political issue
Company B	Simultaneous development of products and services	Gaps and conflicts between different departments	Large scale of organisation
Company C	Flexible team construction	Spending time and effort on team construction Lack of mutual understanding and communication	Losing know-hows and stable working environment in short-term cooperation
Company D	Outsourcing of product development	Addressing unpredictable troubles	Uncertainty of new business and external conditions

3 COMPARISON BETWEEN NATURAL ECOSYSTEM AND INDUSTRY

Allenby and Cooper (1994) have suggested the potential of nature as a reference for developing sustainable economic systems by introducing ecological succession model of Odum (1969). The summary of this model is shown in Table 3.

Table 3. Ecological Succession Model (Odum, 1969)

Ecosystem Attributes	Developmental stage	Mature stage
Nutrient cycling	Open	Closed
Growth form	For rapid growth (r-selection)	For feedback control (K-selection)
Production	Quantity	Quality
Food Chain	Linear	Weblike
Species diversity	Low	High
Information	Low	High
Life cycles	Short, simple	Long, complicated
Stability	Poor	Good

In the model, the attributes of systems in developmental and mature stages were compared. The communities in the developmental stage possess abundant resources and energy, and rapid growth strategy is more competitive under such conditions. Therefore, organisms concentrate on increasing the number of entities rather than concerning about the amount of resource or energy they utilise. Thus, nutrient and minerals are consumed by open cycle without re-utilising the outputs of the system as resources. The growth of population is accelerated until the amount of available resources and energy reach the limit. The community of organisms in developmental stage show linear food chain, low level of species diversity and information exchange, short and simple life cycles. These characteristics are reflected on poor stability of a community so easily broken when it encounters environmental changes.

The tendency of natural ecosystems in developmental stage is similar to that of artifactual system in which mass production has occupied the mainstream of industry and economy. At the beginning of the mass production era, companies could take advantage of abundant resources and their business has been developed in the direction of producing, selling and consuming more products faster. Most of product life cycles follow open cycle, in other words cradle to grave, so the resources that were input to a manufacturing system come out of the system as an output in the form of waste and pollution that can seldom be reused and circulated in the system. The growth of industry has depended on resources so now exhaustion of resources is threatening industrial development.

When resources and energy are deficient, natural ecosystems enter the mature stage. In this phase, nutrients and minerals can be recycled so the entities in the system can survive without input from the outside of the system. They utilise feedback control to survive under K-selection pursuing qualitative growth in dynamic equilibrium. A community in the mature stage consists of a variety of species forming weblike food chain structure. They have longer and more complicated life cycle and more resistant to the environmental changes compared to those in developmental stage.

These two stages in natural ecosystem also can be mapped on the industry life cycle which was introduced by Grant (2010) (Figure 1). From the emergence to the extinction of an industry, it goes through 4 phases: introduction, growth, maturity and decline. Also companies apply different strategies depending on the developmental phases. On the introduction phase, they attempt to improve the attractiveness of products through product innovation to strengthen the position in the market. After entering the growth phase they focus on process innovation to reduce the production cost and to raise product reliability. In addition, Tukker and Tischner (2006) suggest PSS as one of the strategic innovation method to extend the industry life cycle at the end of the maturity phase. In general PSS is considered to be an effective innovation strategy to cope with economic and environmental limitations

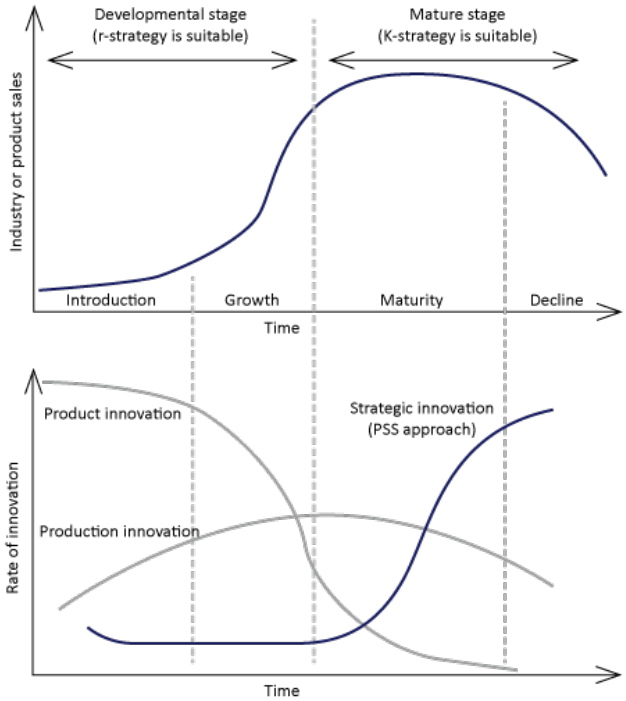

Figure 1. The industry life cycle (Tukker and Tischner, 2006)

such as market saturation, environmental pollution and resource exhaustion. When a firm adopt PSS strategy, it can earn sustainable profits by differentiating its offerings and revising the profit structure. Also it can be greener as it provides its customers same or more values with same or even less environmental pressure. If the industry succeed in strategic innovation like PSS, the companies can transfer to the trajectory of new life cycle curve and survive in the market.
From the perspective of natural ecosystem, PSS approach is equivalent to the strategy to extend the lifespan of a community (Figure 2). In nature, a community follows r-selection when the population is low and when plentiful resources including food and habitat are available. As the population increase and the resources get deficient, it changes its strategy into K-selection to survive in an environmental change. If a community does not adjust its strategy to surrounding circumstance and situation, it would be extinct. In the same way, if the traditional businesses based on the mass production system arrive at maturity phase, they should pioneer new industrial sectors for their sustainable growth through taking suitable strategic innovation. Unless, they would be weeded out as the extinct species in natural ecosystem have been. Since the mature communities in nature have mastered the similar situations, their successful strategies could be a good guide to the strategic innovation for the companies.

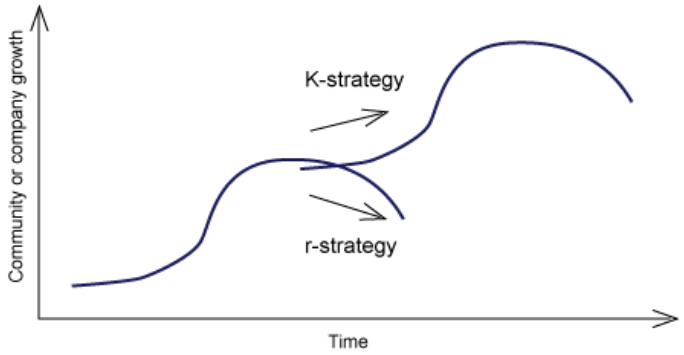

Figure 2. The impact of r/K strategies on the lifecycle of a system

Meanwhile, Barabási (2014) asserts the importance of organisational structure in information-based economy. In the industrial economy, most of the manufacturing firms are built into tree structure in which the members take on specialised non-overlapped tasks. In terms of efficiency, it is the most optimised shape for mass production under economy of scale. However, this hierarchical structure is not supportive for effective information exchange due to the gab of information density between higher and lower level of hierarchy. Although the most advantageous position to obtain direct information about users and market condition is lower level, business strategies are usually managed in top-down direction. Consequently, tree-structured companies are inflexible in adjusting to the change of market situation. In contrast, the author depicts network structure as more suitable structure for dealing with information. Compared to the hierarchical connection in tree structure, workers in a network structure have equal and complicated relationships with their co-workers. When making decisions they take a bottom-up approach based on the up-to-date information collected through close interaction so they can flexibly come up with changeable user needs and market condition.
In terms of organisational structure, information exchange and diversity of entities, this comparison also shows similar pattern to the comparison between developmental communities and mature communities in nature. Reminding the organisational problems of PSS companies from the previous section, these comparisons raises a question about proper organisational structure for a PSS, in which information is more valuable than in manufacturing-oriented business.

4 DISCUSSION & CONCLUSIONS

4.1 The organisational problems in PSS companies

Considering its background such as market saturation, resource exhaustion and pollution, the introduction of PSS can be regarded as in line with the strategic change from r-selection to K-selection in natural ecosystem. The problems in industry would be more complicated than those in nature, but the two systems have common goals in terms of survival in circumstance change.

However, while the systems in nature have adjusted their organisational properties to their new strategy, PSS companies have maintained traditional organisation structures so have been suffering from difficulties in communication and decision making in their new businesses. Even though the companies attempted to solve their organisational problems, it was not easy because the obstacles such as organisational culture, political issues and short-term cooperation interrupted them.
Nevertheless, it is essential for the companies to overcome the organisational problems to achieve better performance in their business. The smooth communication between different departments and different companies can encourage the cooperation between them based on common goals and consensus. Besides, decentralised decision making would enable an organisation to find an optimised solution for entire organisation from a broader perspective. In addition, a company would be able to cope with the environmental changes and unexpected crisis when the information is processed appropriately and delivered to the right teams and organisations quickly.
The findings related to the organisational properties present that the information management, organisational structure and relationships among stakeholders are interdependent. That is, not only infrastructure for communication but also internal and external connection structure of organisations should be taken into account in PSS design. It can be supported by the assertion of the academic fields dealing with organisation and systems which have emphasised the importance of harmony among organisational properties such as structure, management system and role of individual members (Grant, 2010). Nonetheless, it is hard for firms to identify the best strategy and structure for them because of the complexity of market and industry environment (Nelson, 1991). Therefore, how the internal and external organisational structure should be set to support PSS companies need to be discussed further. Also the obstacles in organisational improvement should be taken into account.

4.2 Potential of NID approach to solve the organisational problems

The comparison between the artificial system and natural ecosystem implies that the organisations in mature ecosystem can provide the clues to construct desirable organisation for PSS business. Mature communities in natural ecosystems already have the qualities that were required to overcome the problems observed from PSS companies such as intensive communication and feedback, network structure and stability. That is, the features of mature communities demonstrate the desirable developmental direction of PSS. Therefore, PSS developers can learn from the mature communities in natural ecosystem about how they should design the organisational structure, construct relationships among stakeholders and manage communication and decision-making process.
However, the insight on the potential of NID approach in the current study is mainly based on literature reviews so still conceptual and abstract. To clarify the relationship between two different kinds of systems and assure the effect of natural ecosystem as a reference for organisation design, sufficient cases of corporations and natural ecosystem need to be studied and compared.
Moreover, the fundamental differences between natural ecosystems and artifactual systems also should be considered. For example, humans have more complicated needs, emotion and relationship than animals or plants do, and these factors influence a lot on their work performance. These differences affect system level NID more than form or process level, so applicability of cases should be examined based on clear understanding of similarities and differences between natural and artificial systems.
Lastly, the elaboration of tools and methods are required for practical application of NID approach to designing organisational structures and communication strategies. For instance, if the cases of natural ecosystem are indexed by the applicable situations and problems of artifactual system, the case database could be used more effectively. Existing tools or methods for biomimetic product development would be a good guidance on how the data about artificial and natural system should be linked and organised.
Although there are some insurmountable obstacles such as organisational culture and political conflicts, organisation design would be an opportunity to make the best use of designers' unique skills - ability to understand the latent needs and to encourage collaboration of stakeholders (Bhömer et al., 2013).

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