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ENABLING FACTORS FOR MANAGING INTELLECTUAL RESOURCES IN ENGINEERING DESIGN

J. Mela, T. Lehtonen, A. Riitahuhta and T. Juuti

Keywords: knowledge, intellectual resources, management, engineering design

1. Introduction

Using intellectual resources available, to produce long-term competitive advantage in engineering design, requires evolution in the ways strategies are executed. This means linking effective knowledge management methods to business strategies, and strategies to employees. Teams and groups can be seen as socially constructed phenomenon that integrates individuals and organizations. Indeed, the intellectual resources management in engineering design should not consider only individual or organizational factors, but the forms of social coalitions between these two resources.
The goal of this paper is to apply existing knowledge management models with the experience of the authors, to recognize enabling factors for managing intellectual resources in engineering design. Paper first discusses objectives, methods used, and terminological orientation of the study. Defining the methodology and terminology, is seen as an important influence for the validity of this research. After the introduction, engineering design perspective is connected to the models originally presented by Nonaka et al. 2000. Selection of the models presented in this paper is done as an objective to recognize the basis for an effective management of intellectual resources in the field of engineering design. Models discuss the form, time, place and context in which the information and knowledge is shared and exploited.
The second chapter crystallizes theoretical foundations presented. Resulting profile creates a synthesis of the ideas presented and the applications they can take in engineering design. In the third chapter case study from the field of engineering design is presented. Case illustrates the forms of intellectual resources management in value chain networks, and describes in practice how the theoretical approach of this paper can be applied in real world. Case study is based on research executed during the years 2004 - 2007 in Nordic shipbuilding industry. Finally study points out the conclusions of the theoretical foundation and its applications.

2. Creating a foundation for managing intellectual resources

2.1 Objectives and methods

Managing organizations intellectual resources derives from its business position and strategic goals. To understand the business logic, under which certain company operates in, the business field and value chains it operates in has to be understood. Roles and structures in the networks, formed by the organization to control its internal processes, define the efficiency of intellectual resources utilization. This process forms the basis for creating the right kind of intellectual resources management methods to respond the informational needs of the company in a long term.

By creating an understanding of how organizations intellectual resources are connected to time, place, and social context, and how they are shared inside the company, it is possible to perceive more modern perspective for managing these resources in engineering design. Modern methods of knowledge management are needed because it is ineffective to use traditional resource management strategies to manage intellectual resources which also function under such laws as inhumane interaction and social relations.

The main goal of the research is to answer the question, how can the models presented in this paper to be applied in the field of engineering design to ensure companies competitiveness and R&D efficiency by effectively managing intellectual resources. Study aspires to achieve an understanding of the prerequisites enabling management of intellectual resources, so that companies are more capable to recognize, share, and reuse these resources.

As resulting from the research question of applying the critical knowledge management models in the field of engineering design, the methodology of this study is based on empirical studies and ethnographical research method of the authors during the recent years. Research is mainly problem based as a consequence of the participation of the authors in several research projects executed during the years 2004 - 2007. Research is applied by the means of the critical rationalism, approach in which models and methods rising from the needs of the project client companies are improved during the research to provide better solutions to research problems. Figure 1 overview the term intellectual resources and terms related to it in this research.

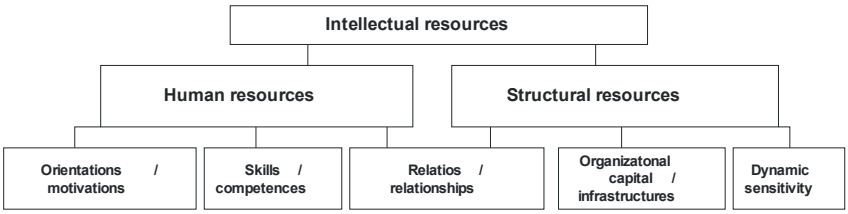

Figure 1. Definition for the term intellectual resources

Figure 1 indicates that intellectual capital occurs on different levels of social relations. As an example, relationships between individuals can be separated from relations between groups or organizations. So this category represents both, human related- and structural resources related characteristics.

The problem that has become familiar for the researchers in the field of intellectual resources management is the difficulty of measurement of intangibles. Also, as well as in many other research fields, it has turned out that adapting a solid terminology to describe the issues of intellectual resource management is very difficult. The main influence for that is the impact of many different science fields and schools, whom angles have to be considered in order to create extensive terminology.

Andriessen published 2004 a survey about measuring and valuing intangible resources. 25 methods found in a literature were presented. According to Andriessen these methods could be grouped in to three categories: 1. Solving internal management problems by developing methods to improve the management of intangibles. 2. Methods to improve the external reporting of organizations. Aim is to discover ways to provide additional insight into investments of intangibles and methods for reporting the financial value of intangibles. 3. Pricing the intangibles or otherwise estimating the value of the elements of intangible resources. According to Andriessen's classification, this research settles to the first category by aiming to apply and improve existing methods for the managerial needs of engineering design.

2.2 Engineering design perspective

Managing and exploiting intangibles such as intellectual resources, company needs accomplishing its strategic goals, means that it has to be able to recognize these resources. It is not obvious that organizations could point out the core intangibles needed, to realize their strategic objectives (Life Cycle Business project). Intellectual property available to use, however cannot be systematically

exploited before it has been recognized, captured and refined in order to get the "best pieces" out of the information flowing through the organization.
It is important to understand the business field we are dealing with when discussing about the field of engineering design. Demands directing the structural characteristics of products and services and the value chains that company operates in also form an important synthesis for recognizing strategically important intellectual resources. To evolve engineering design methods, attention of researchers should not only be focused on the entities to be managed, but the relations that guide the synthesis formed by those relations, processes.
Figure 2 describes a framework for defining the relations between organizations strategy, value chains it operates in, and the product and service structures. Understanding the relations between these elements points out the strategically important intellectual reserve for the organization. Management of networks, company operates internally and externally, defines the efficiency of processes guiding the utilization of resources. The centric idea in the figure 2 is to present the relations between the structural characteristics between the company offering and the processes delivering them. Understanding the nature of these processes inside and outside the organization enables charting of important intellectual resources.
Figure 2 indicates how structuring of products and services, is guided by the parts of the value chains company operates in. Product structures need corresponding value chains while value chains are guided by the companys strategic objectives. While structural characteristics of products and services advance some value chain implementations, they also limit the possibilities of other ones. It is not difficult to see that certain delivery processes also serve certain offering structures better than others. There might also be some structural elements in product offering, that are usually targets of customer variation. Therefore it is practical to emphasize the variable characteristics of these elements in product design and guide the value chains operations to support the kind of product structure. On the other hand, business strategy may contain certain innovations, such as new technology, forming the central competitive advantage for the product offering.

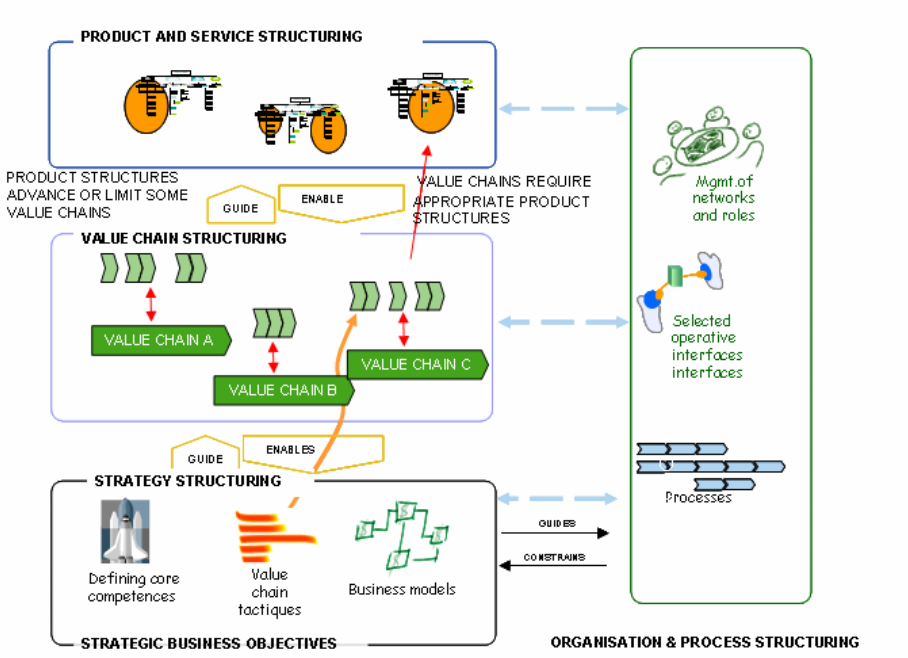

Figure 2. Dependences between product and service structures, value chains and business strategies

Therefore design and value chain solutions have to promote these strategic objectives. In both, customer driven and innovation driven design approaches, we need to understand not only the needs to be fulfilled but the internal relatios between the engineering design- and delivery processes. The understanding of these processes is often in a hidden form, stored as organizational infrastructures, skills and competences of workers and groups.
Strategic objectives also guide the selection of external networks organization operates in. The forms of networking organizations tends to prefer, often depends both environmental factors and strategic goals.
The field on engineering design, described in figure 2, unquestionably includes knowledge-intensive activities, both in its internal and external operations. Knowledge management is realized in a form of management of networks and roles in the organization. It means that there have to be some logic to structure organizational infrastructures, such as networks, competences and roles in order to exploit intellectual resources flowing through internal processes. Model for this kind of approach is presented in the next chapter.

2.3 Setting the basis for managing intellectual resources

Knowledge management processes realizing the methods to manage intellectual resources, have to be integrated in every-day practices converting engineering design as operations, usually realized by employees. Linking daily behaviors of knowers with the knowledge they employ, means implementations integrated in employee's daily actions and organization structure as well as its culture. The kind of approach described, requires methods that consider the individual, social and organizations culture -related factors in managing intellectual resources. Importance of observing the social factors in intellectual resources management research cannot be neglected. According to Davenport 1994, two-thirds of the information and knowledge, managers need, comes from face-to-face meetings or phone conversations and only one-third from the documents. "Too many knowledge projects focus only on stocking the shelves with knowledge, with little regard for why or how people might be motivated to draw on a piece of knowledge in their work routines. Indeed, we still know very little about the favorable circumstances that stimulate people in organizations to create, share or apply knowledge" (Davenport & Prusak 2000). This statement also goes to teams and organizations. The problem pointed out by Davenport and Prusak is a centric goal in examination of the models in this paper. There has been very little research, capable pointing out the social context -point of views, critical for managing organizations intellectual resources - specially from engineering design point of view.
Love et al. 2005 emphasizes that for example learning must be integrated with current tasks, not only to meet present goals, but also to develop and retain knowledge for future organizations needs. As an example, new product development requires adaptations of knowledge in new problem orientated situations, thus an organizational experience and knowledge sharing between individuals and their coalitions. With successful planning and execution, product development projects also produce an important informative competitive advantage to organization as the form of data, information and knowledge created, refined and shared during the development process. The more progressive, organizations knowledge management methods in use are, the better they manage to exploit the knowledge arising from internal activities, such as product development process. So, the product development process can be seen as package of features, functions, transformations and benefits, containing inputs and outputs specific to a certain development process. The value achieved from the outputs, as in form of the design reuse, is mostly determined by the way knowledge management is carried out in organization.
Figure 3 presents a process adapted form Nonaka, Toyama & Konno 2000, illustrating the main elements in managing organization's intellectual resources. Figure describes the strategic model of knowledge utilization from strategic to operational level. The uppermost goal of the model is the same as in information and knowledge management sciences fundamentally: to promote and sustain organizations position in markets. Model combines the tree main elements of knowledge creation, SECI-process, the context of knowledge creation (ba), and the knowledge resources of the organization. Relations of these tree elements are guided by the visions derived from business strategy.

These visions have to be able to create synchronized structures, adapting knowledge management for the needs of the organization.
Peoples values and beliefs affect strongly for what they choose (consciously of unconsciously) to observe. People also organize observed information differently depending on their personal characteristics. Left-top corner in figure 3 describes the processes of knowledge sharing in organization. These processes are described as a form of SECI-model; socialization, externalization, combination and internalization of knowledge. Knowledge consists of internal tacit-knowledge and explicit documented knowledge, which are shared between individuals following one of the four processes of SECI.

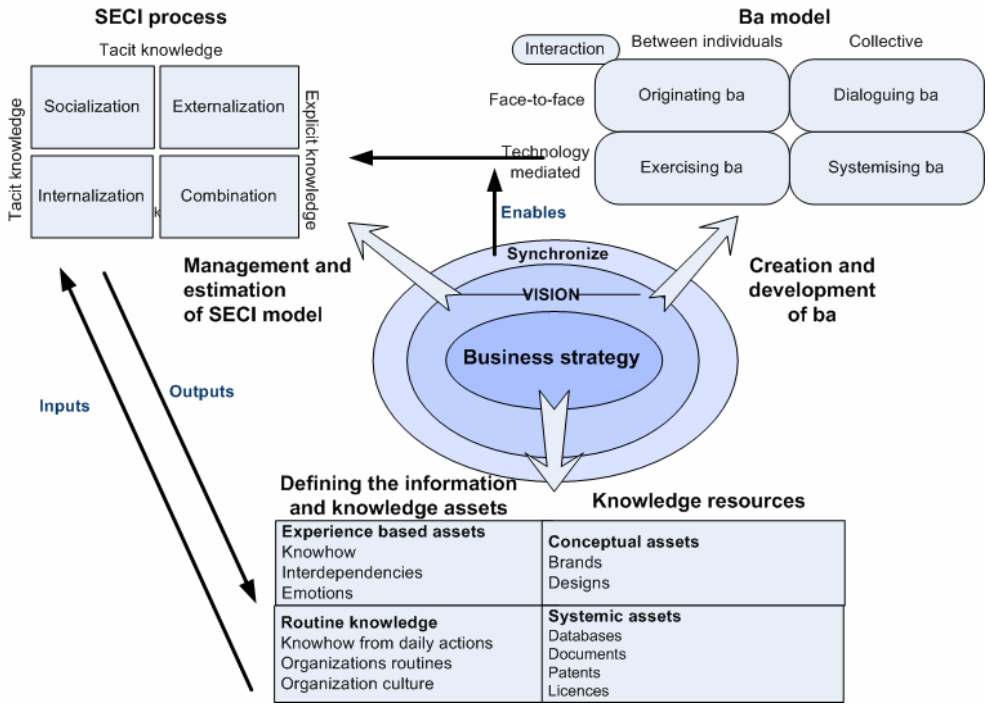

Figure 3. Strategic model of knowledge utilization

To enable the SECI-process of knowledge sharing, the context of thinking and acting in certain environment has to be created. Term "ba" comes from Japanese "basho" and refers to the divided context of thinking and action. Ba is based on theories of Kitaro Nishida, and research work of Hiroshi Shimizu. The model of ba on the right-top corner links time, space and place into SECI-model, and creates a foundation for knowledge sharing and transformation. The foundation in four areas has to be considered in organization, to effectively manage the intellectual resources. Originating, discussing, systemizing, and exercising in the forms of social (face-to-face) and technology mediated interaction, represent the areas of social contexts enabling the processes of SECI-model. Figure 3 classifies organizations knowledge resources in four categories. They are founded either on individuals experience, organizational concepts, knowledge included in daily routines, or systemically organized warehouses. Last mentioned category is the most traditional in organizations. Figure illustrates how this data and information based standpoint for knowledge management represents only a fraction of organizations intangible resources. However this, fairly narrow, viewpoint observing only data and information -related intellectual resources stands out to be the most common one.
Davenport & Prusak 2000 have used a term "management of attention". It means understanding how knowledge is allocated by individuals and organizations knowing how to capture it more effectively,

and using technology both to acquire and protect it. Expression “management of attention” clearly points out an aspect of management research that is starting to get more and more attention. Researchers are starting to recognize increasing need to consider human-related factors in optimizing the productivity of engineering design. One of the main goals of the model presented in figure 3 is to manage the attention of individuals and groups they form (using ba) to enable management of intellectual resources.

Benefits of applying the model

1. Model can help managers to understand how knowledge can be imported and exported from the organizations internal engineering design processes that need intellectual capital to get realized.
2. Model indicates how organizations are able create a culture that promotes recognition, creation, and use of intellectual resources through management of attention.
3. Model works as a template for recognizing the crucial factors and drivers for different forms of individual interaction in knowledge sharing and -exploiting processes.

3. Theoretical synthesis

3.1 Recognizing the important intellectual resources among intangibles

Chapter 1.2 emphasized the importance of recognizing the framework formed by networking organizations strategy, value chains it operates in, and processes as a relation to product and service structures, in order to manage intellectual resources. It did not however explicate how this might be done. According to Viedma 2002 and Andriessen 2004, recognition of the critical intangibles arises from the organizations core competencies. Core competencies define which intellectual assets are important for the company. Then, recognizing the invisible knowledge activities and putting them in to right context is the key for successful management of intangibles. Figure 4 represents the basis for recognizing organizations critical intellectual resources.

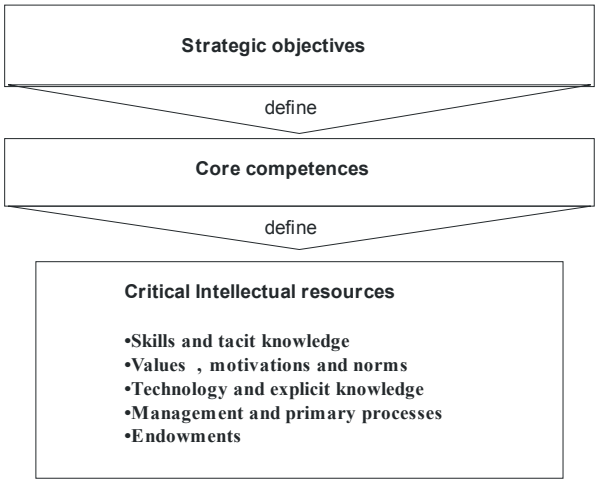

Figure 4. Process of defining critical intellectual resources

Viedma 2002 defines intellectual resources as equal to company’s core competences. We however emphasize core competences strict relation to organizations critical, not all, intellectual resources. By recognizing the intangibles needed to realize organizations core competencies, company can name the key- intangible success factors for fulfilling its strategic goals. That way it is also more capable of

eliminating non-value adding activities from processes of engineering design. This saves such finite resources, as time, money and energy in its different forms. Also knowledge itself is a finite and limited resource, which means that there might not be available all the intellectual resources needed to fulfill core competences defined. Besides of intellectual resources critical for realizing organizations strategy there is value-adding intellectual resources that add value to the organizations core-functions. Communicating with the customer, as an example, can create social innovations and improvements for company's offering forming important intangible value-adding resource, however not critical to company's success

4. Case study: Management of intellectual resources in decentralized organization networks - value chain management as a tool for the reuse of intellectual property

This case study was executed during the years 2004 - 2006. The goal was to chart the forms of value chain management in decentralized organization network. Study indicates the importance of identifying the different forms of partnerships, ownerships and methods of payments in value chains. Study is based on experiences of researchers co-operating with Nordic shipbuilding industry. This area of industry is extensively networked organization structure in which hundreds of contractors and sub-contractors participate of the delivery process of cruise ships. Besides the actual work, sub-contractor often delivers design work and process control tasks.

As one driver of the study was an observation that ship-deliveries often involved remarkable amount of operators representing different motives, objectives, and viewpoints. Sub-contractors and contractors might have differing opinions about the delivery processes, their details, or even the ownerships and payments during the delivery process. Communication between sub-contractors and main contractor can also form a challenging task inside the value-chain network. Overall, the need for applying the strategic model of knowledge creation (fig. 3) in order to create human related and organizations structure -related foundation (fig. 1) for the needs of value chain management, was the subject of research. Interaction between individuals and teams in the form of social contacts and technology mediated interaction in supply chain, formed the foundations of knowledge management. First stage for applying the strategic model of knowledge utilization was the definition of possibilities of the different delivery types. In cruise ship delivery four different methods appear:

4. Main contractor centred project delivery
5. Turn-key delivery in which ship is divided spatial areas, delivered by the subcontractors
6. Modular ship delivery consisting of configurable parts
7. Network based delivery in extended enterprise.

In different types of deliveries, different delivery process types are possible. Value chain management connects to engineering design in a way, in which certain product and service structures are suitable for certain delivery processes and some are not. Network based delivery illustrates the extreme example of the form of "democratic" partnership, in which equal network of operators form an extended enterprise consisting of equal business partners. In this kind of approach partners equally share the profits and losses following from the delivery. In main contractor centered project delivery, as another extreme, the main supplier (in this case the shipyard) controls the whole delivery process. Any forms of real partnerships do not exist, but the main supplier buys the parts of the delivery, it cannot execute by itself, from the sub-contractors.

In the networking study, a classification of ownerships in shipbuilding industry were made. Moving from shipyard-controlled delivery towards network-controlled forms of the ownerships in value chain, transition of methods of co-operation is remarkable. In main contractor controlled area, methods of payments are usually non-recurring and partnerships do not occur. So, extensive part of the value of design process places in earlier parts on value-chain, as a comparison to the network-based value chains. According to research executed in shipbuilding industry, the delivery types and forms of the ownerships seem to be tied, at some level, to each other. Research indicated, the more network base delivery methods was observed in value chain, the more partnership-related the relations inside the value chain were. This relation however was not unambiguous. The methods of payments, were

chosen to describe the form of the supplier – sub-supplier relations. The aim was to indicate that certain types of contracts promote certain delivery types.

Process of knowledge utilization

Teams are often characterized according to risk and synergy resulting from their interaction with different teams and team members. Morrison and Kennedy 1996 emphasize that interaction formed by the result of different participants, brings in the need to collaborative data, knowledge, and other relevant information, these team members contribute. Quite often teams and their networks represent multidisciplinary participants operating, not only towards different goals but also with varying use of terminology and knowledge. From value chain perspective this means that different parties of the delivery process might not only have different perspectives for processes but they might also have disagreements about responsibilities and ownerships. It depends strongly on the types of the partnerships practiced inside the value chain, what kind of possibilities there is to utilize knowledge available.

Positioning of network based delivery type and shipyard controlled delivery type in the model of knowledge utilization is now reviewed (Fig. 5). These two delivery types were chosen because they represent opposite starting points in partnership creation. Research work in shipbuilding industry indicated that shipyard-controlled and network based deliveries represent opposing forces of ba implementation. In shipyard-controlled approach enabling factor for ba is the main contractor itself, as in network based approach all the actors together form the possibilities for the realization of ba. In practice, the knowledge creation in main-contractor driven enterprises is often based basically on systemizing ba. In a work community, information and knowledge needs often occur in a form of certain need. Often these needs acquire some communication between teams and individuals, so that they can take a certain form. Ba represents the frame for the communication between the members of the value chain. Possibilities for knowledge sharing seem to depend on the forms of the partnerships inside the value chain organization.

From the SECI model point-of-view, the processes of knowledge sharing occur, in main contractor centered approach, most in the area of explicit knowledge. In network based value chains the basis for the processes of socialization, internalization and externalization can be realized more potentially. The main reason for that is the partnership-based relationship model, in which individuals and teams are more capable and motivated to share knowledge. In the field of knowledge resources, sharing the knowledge, in main contractor controlled approach, is mainly based on systemic assets as documents or instructions. Experience and routine knowledge based assets are left with less examination compared to network based approach.

Overall, as considered from the process of knowledge utilization perspective, the partnership oriented network based approach for the management of value chains, as a comparison to main contractor centred approach, would advance the methods of knowledge use in ways indicated below:

1. In partnership based approach the structural definition of the delivery can be done in earlier stage of life cycles and services can be sold as more strictly defined entities. In main contractor centred approach this would limit the possibilities to choose between different sub-contractors. The design work can focus on different parts of the life cycle of the delivery, according to the delivery type.
2. In partnership based value chains, sub-contractors are more motivated to invest in R&D. In main-contractor approach this would be a risk because of the uncertainty of the future deliveries. Intellectual property rights can also turn to be a difficult issue.
3. Constant changes of sub contractors cause internal variations in quality and architecture in main contractor based delivery. This prevents internal learning, knowledge creation, liability distribution, repeatability, communication, design reuse, process rationalization, and dilutes quality.
4. Network based approach contributes the possibilities of modular products and services enabling the advantages of modular product and service structures. This finding is based on an observation that closeness of business relation correlates with the possibilities to achieve

common agreement about the structural characteristics of the delivery in early stages of life cycle (Mikkola 2003).

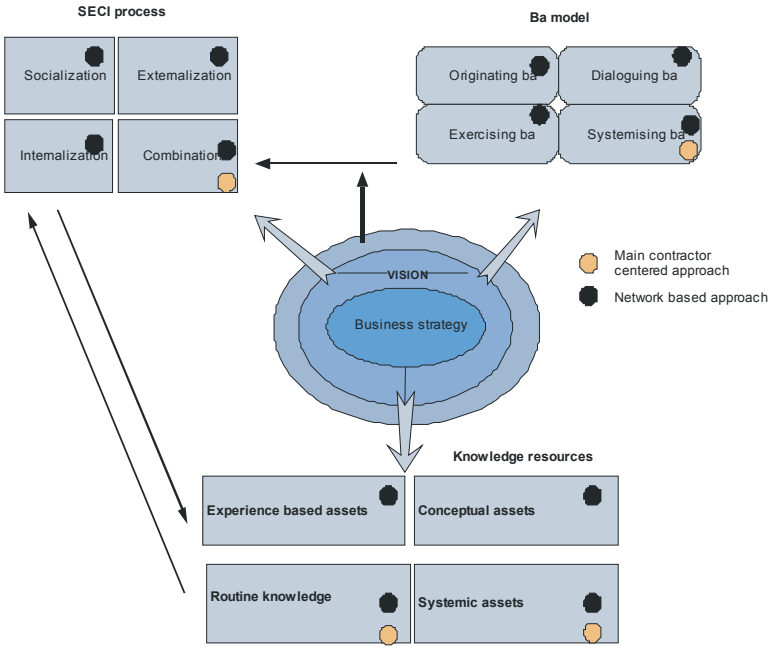

Figure 5. Fifferent delivery types from the knowledge sharing perspective

In shipbuilding industry, 80% of the total delivery costs are defined in early stages of the delivery process. Only 20% of the costs however is used in the early stages. To attain financial savings, the design work should be realized in early stages of the delivery life cycle, where the savings still can be made. Another major impact to the total costs consists of organizations ability to reuse its intellectual resources so that people do not have to learn same things all over again in several delivery projects. It appears that network based delivery, supporting partnership-based knowledge sharing culture in value chains, would be preferable from the knowledge management point-of-view.

5. Conclusions

The goal of the study was to apply knowledge management models presented in the field of engineering design to find the aspects to effectively manage intellectual resources. Models presented in this paper discussed the form, time, place and context in which the information and knowledge is shared and exploited. Case study indicated the aspects, knowledge management faces in the value chains and the partnerships they include.

As a driver of effective management of intellectual resources is an understanding about the relations between different parameters and motives, inside and between organization networks. It is the synthesis formed by these relations in organizations that form processes guiding organizations most important resources; employees, towards effective sharing and utilization of knowledge. In this research relations between organizations strategy, core competences, value chain position, value chain

networking, and product & service structures were emphasized as building blocks for effective management of intellectual resources. The synthesis formed by organizations networks and roles has to be built in a way that they support organizations strategic objectives.

Intellectual resources cannot be systematically managed through measurements, even in the field of engineering design. Indeed, the engineering design perspective also requires adaptations of knowledge management methods. Managing intellectual resources in engineering design is also a social matter. Research of intellectual resources faces several problems concerning the characteristics of social sciences. First of all, occurring from the nature of social-related sciences, objects of research are partially created by the research methods targeted to them. This means that scientists have to construct the reality to define it. Social world, on the other hand, alters while it is constructed by the observers, which makes it difficult to form any extensive laws aiming to dominate it. In practice this makes it difficult to chart the variables of a social world in engineering design, using common methods as empirical studies, without influencing the answers. The strategic model of knowledge utilization succeeds to consider social-related issues in intellectual resources management by creating the concept of context for knowledge sharing and utilization.

Life Cycle Business project executed during the years 2005 - 2007 indicated that companies often did not systematically recognize their needs according to intellectual resources. This study suggests that well managed definition of core competences arising from business strategy, is the key to effective recognition of critical intellectual resources. Understanding the business field organization operates in, forms the basis to strategy development able to support both, internal and external networking.
Strategic model of knowledge utilization represented the foundation, for the management of intellectual resources. It included both, human related and organizations structure related aspects. According to models and the case presented in this research several conclusions can be made. To manage individuals, teams, and organizations attention business strategies have to promote utilization of intellectual resources. Model of strategic knowledge utilization can advance understanding about organizations networking that links the strategic goals and intellectual resources to each other. It is not, however, a map for executing these goals. Strategies chosen to manage the relations and processes strongly guide company's capability to achieve share and reuse knowledge.
Strategies have to fit to value chains they are ordered to function in. It indicates that, systematic selection of the forms of the partnerships and value chain networks is advisable. This will also guide the structuring process of products and services to promote design and other intellectual resources reuse. Whether the company chooses to practice extended enterprise based partnership relations or distant arms-length relations with other companies in the value chain, defines its possibilities for the effective utilization of intellectual resources.
Shipbuilding industry case also indicated that investing on design work, communication, and design reuse in early stages on development process of the delivery project, promotes organization networks possibilities to achieve cost advantages in latter stages of the value chain. Another indication pointed out that the certain types of contracts promote certain delivery types and forms of the partnerships. The contracting policy should be tied more strictly to strategic objectives of the organization. Overall, well defined strategies also guide to recognize important intellectual resources by pointing out the knowledge needs for realizing the core competences. Different levels of information and knowledge exchange exists promoting the utilization of intellectual resources. Communication exists between individuals, teams, units and organizations. Culture represents a framework for all of the levels of communication. Whether it is organizational, national, or even religious characteristics that most guide certain communication process depends on a situation. To crystallize the conclusions, following suggestions are made in this research about things to be observed when the aim is to manage organizations intellectual resources:

1. Understanding the business drivers guiding the recognition of intellectual resources:
- **Business environment & business strategy** and the requirements they direct to organizations internal and external operations

- Recognizing the **value chains** company operates in and their relation to **product and service structures –** structural characteristics are to fit to strategies executed in value chains, processes that deliver them, and customer needs (push-pull)
- Defining the **core competences** derive from business strategy and business environment
- Recognition of **critical intellectual resources** according to core competences
- Defining the **networks and roles** guiding the knowledge management processes that create the synthesis – business strategy controlled process

2. Understanding the synthesis formed by internal operators and processes – management of networks and roles guides this synthesis
3. Creating social environment that is favorable for sharing knowledge (management of attention - ba)

- **Common goals** as drivers of individuals and partnership form-of relations
- Understanding the **drivers of individual behavior**: altruism and reciprocity, (repute), values and beliefs, rewards, job security, promotion or another assessment set by the executives, influencing the emotional sides of the individuals.
- Managers as the **role models** for knowledge behaviors
- **Rewarding** people for sharing knowledge and using business intelligence
- **Educating** all employees in the area of knowledge finding, sharing and creation
- Enabling the **transparency of processes** for the employees
- **Trust** in an organization and society in a way which workers are able to see as actions. Trust is connected to the knowledge change, trust increases knowledge chance and other way around.

4. Recognizing the critical intangible resources according to four categories of knowledge assets and core competences.
5. Evaluation of decisions and decision making on the basis of knowledge used to arrive at them. "Not all knowledge is equal".
6. Understanding what "management of attention" and design reuse means to the company and what are the benefits arising from it.

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Johanna Mela, M.Sc
Researcher, Project Manager
The Institute of Production Engineering
Product and Production Development Laboratory
Tampere university of technology
P.O. Box 589, 33101-Tampere, Finland
Email: johanna.mela@tut.fi