St. Petersburg University

Graduate School of Management

Master in Information Technologies & Innovation Management Program

KNOWLEDGE TRANSFER BETWEEN PRODUCT LIFE CYCLE PHASES IN NUCLEAR INDUSTRY

Master's Thesis by the 2nd year student

Concentration: MITIM

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St. Petersburg

2017

ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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I, Sichkarenko Anastassiya, second year master student, program 38.04.02 «Management», state that my master thesis on the topic «Knowledge transfer between product life cycle phases in nuclear industry», which is presented to the Master Office to be submitted to the Official Defense Committee for the public defense, does not contain any elements of plagiarism.

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Описание цели, задач и основных результатов	Жизненный цикл сложных инженерных систем (атомных электростанций, буровых платформ, газовых турбин, самолетов и т. Д.) длится десятки лет - от проектирования до вывода из эксплуатации. За это время система проходит несколько этапов и сопровождается большим объемом информации, таких как техническая документация и нормативно-правовая документация. Во время создания и эксплуатации этих систем используется и накапливается большое количество неявных знаний. Фазы жизненного цикла тесно связаны друг с другом, и, следовательно, успех всего проекта зависит от грамотно выстроенной передачи знаний от одной фазы к другой и от использования опыта предыдущих проектов. Целью данной работы исследование методов и техник, используемых при передаче знаний между фазами жизненного цикла продукта. Методология исследования заключается в сравнительном кейс-стади 3 компаний, работающих в области атомной энергетики в России. Основной источник данных для исследования интервью, публикации и документация компаний. В результате работы представлена модель, которая показывает, как осуществляется процесс передачи знаний между стадиями ЖЦ на примере АЭС. Описание процесса также сопровождается выделением основных проблем и факторов, которые препятствуют эффективной передачи знаний.
Ключевые слова	Передача знаний, управление знаниями, методики передачи знаний, барьеры, жизненный цикл продукта, управление жизненным циклом.

ABSTRACT

Master Student's Name	Sichkarenko Anastassiya
Master Thesis Title	Knowledge Transfer between product life cycle phases
Faculty	Graduate School of Management
Main field of study	Information Technologies & Innovation Management
Year	2017
Academic Advisor's Name	Dmitry V. Kudryavtsev
Description of the goal, tasks and main results	Life cycle of complex engineering systems (nuclear power plants, drilling platforms, gas turbines, aircraft, etc.), from initial design to decommission, spans dozens of years. During this time period the system goes through a number of different phases and is accompanied by a large amount of information, such as technical documentation or legal requirements. These systems are designed and maintained by people, who accumulate and apply implicit knowledge of their projects. Different phases of a life cycle are closely related to each other and, therefore, success of the whole project depends, among other things, on a proper transfer of knowledge from one phase to the other and a proper use of previous projects' experience. The purpose of this thesis is to explore particular knowledge management practices and knowledge transfer processes used throughout the phases of a life cycle in nuclear industry. The design of the research – comparative case-study of three Russian nuclear energy companies. The main source of data – semi-structured interviews, publications and documentation. The results of the study is a comprehensive framework organizing KT methods and techniques that are both common for the whole life cycle and specific for separate phases.
Keywords	Knowledge transfer, Knowledge management, Knowledge transfer methods and techniques, Knowledge Transfer barriers, product life cycle, product life cycle management.

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LIST OF ABBREVIATIONS

KMS (Knowledge Management System)

KT (Knowledge Transfer)

PLM (Product Life cycle Management)

LCE (Life Cycle Engineering)

SCM (supply chain management)

EAM (Enterprise asset management)

CAE (computer-aided engineering)

CAD (computer-aided design)

CAM (computer-aided manufacturing).

PDM (product data management)

SCM (supply chain management)

ERP (Enterprise Resource Planning)

MRP, MRP II (Material Requirements Planning)

SCADA (Supervisory Control and Data Acquisition)

CRM (Customer Relationship Management)

VCS (Version Control System)

INTRODUCTION

Life cycle of complex engineering systems (nuclear power plants, drilling platforms, gas turbines, aircraft, etc.), from initial design to decommission, spans dozens of years. During this time period the system goes through a number of different phases and is accompanied by a large amount of information, such as technical documentation and legal requirements.

These systems are created and maintained by people who apply and accumulate lots of implicit knowledge about the projects. Different phases of a life cycle are closely related to each other and, therefore, success of the whole project depends, among other things, on a proper transfer of knowledge from one phase to the other and a proper use of prior projects' experience.

The purpose of this thesis is to explore particular knowledge management practices and knowledge transfer processes used throughout the phases of a life cycle in Russian nuclear energy companies. The study specifically focuses on identifying and classifying knowledge transfer solutions for each of the life cycle phases, in a setting of a nuclear plant project. Anothet goal is to investigate possible barriers to knowledge transfer between phases of a life cycle. The result of this study is a comprehensive framework, grouping commonly used knowledge transfer methods and techniques by the phases of the life cycle in which they are used.

The topic is investigated through theoretical research and case studies of three companies, members of "Rosatom" State Corporation, one of the world nuclear industry leaders. Although these case studies examines the nuclear industry, the life cycle structure of nuclear power plants and other products of the "Rosatom" corporation is similar to the life cycle of other industries that work on complex engineering objects manufacturing. Therefore, findings of this research would be relevant to such industries as well.

First through the literature review, we identify common practices used for Knowledge Transfer and group them into categories with the help of the theoretical framework (Hosseini, 2014), claiming that Knowledge Management basing on four main concepts: People, Process, Technology and Content.

Then, analysis of best foreign practices is provided. Based on the goals of the thesis, the first research question of this work is:

Q1 Which methods and techniques are used for Knowledge Transfer between different product life cycle phases in nuclear industry?

Second research question is aimed at determining obstacles that prevent effective knowledge transfer.

Q2 What factors play the crucial role during the KT process in nuclear industry?

In order to answer these research questions, empirical study consisting of in depth case studies is conducted.

Significance of the Study

The contribution of this thesis is an increased understanding of knowledge transfer processes in nuclear industry with the focus of transfer between different product life cycle phases. Interview results have shown that research question is urgent and relevant for many companies. The literature study makes it clear that massive manufacturing corporations, especially in Russia (Batovrin & Bakhturin., 2012) are interested in solving problem stated in this research. Investigation and better understanding of the barriers that exist in the company could help to solve problems and avoid knowledge transfer-related issues in future. The purpose of the research is to find methods and techniques to organize business units that will ensure effective way of sharing Knowledge and provide the competitive advantage for engineering organizations.

Research Structure

In Chapter 1, theoretical findings that describe product life cycle, knowledge management, barriers in knowledge sharing and possible solutions that exist nowadays are investigated.

Chapter 2 describes research methodology and justifies the choice of multiple case studies approach. It also contains descriptions of the companies selected for case studies.

Chapter 3 contains case analysis and discussions of the findings. Findings include a comprehensive framework organizing KT methods and techniques common for the whole life cycle and specific for separate phases.

CHAPTER 1. KNOWLEDGE TRANSFER IN THE CONTEXT OF PRODUCT LIFE CYCLE MANAGEMENT: RESEARCH DIRECTIONS

1.1 Product Life cycle management

Product life cycle is a process of product creation starting from consumer demand, ideation and ending with a moment of delivery to customer. (Merminod, 2012) The main stages of the life cycle could be defined as design, production, technical operation and realization. However, the stages may vary depending on industry and product characteristics.

The term PLM, used to describe the business approaches to the creation, management and directional use of products related to the product Intellectual capital and information throughout the life cycle (Batovrin & Bakhturin., 2012).

Hui Cao and Paul Folan give in their article (Folan, 2012) a comprehensive definition for Product life cycle management. PLM is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise, and spanning from product concept to end of life-integrating people, processes, business systems, and information. PLM forms the product information backbone for a company and its extended enterprise.

In conditions of strong national culture and inter-organizational differences, the most effective approach to deal with significant knowledge sharing challenges is to provide local boundary spanners with PLM technology. Management of knowledge translation issues proceeds successfully due to mutual reinforcement between PLM and local boundary spanners.

Our interest of study lies on the companies that produce complex engineering products. In this case the main instrument for managing life cycle is the Systems engineering.

«Systems engineering is an interdisciplinary field of engineering and engineering management that focuses on how to design and manage complex systems over their life cycles. » (Folan, 2012) Major part of contemporary complex engineering systems is characterized by high complexity and large scale. Many factors can prevent realization of qualitative system performing the assigned tasks.

Nevertheless, this term describes process from the engineering and Information Technology point of view. Therefore, in this work author discussed not the Product Life cycle management concept itself, but one specific area that has managerial perspective. The author decided to shift interest to Knowledge Management process within Life cycle management.

At each phase of the cycle, engineers and managers must make complex decisions that require and generate a large volume of cost, design, manufacturing, and product information.

This information must be shared effectively and efficiently to assure engineering and manufacturing conformity with design specifications, to optimize the use of scarce resources, and to better manage the concurrent engineering process. (FORGIONNE, 2003)

It is always easy to either buy the ready-made technologies or implement known best practice approaches, but neither of those approaches guarantees success because they can miss important information of the organization parts and can be easily copied by the competitors. A competitive strategy should be able to give the organization a unique quality, which is not replicated easily.

Any chosen technical solution should be accompanied by the development of special culture that cultivate different capabilities and skills in the organization, motivate the usage and create procedures. Great manufacturing strategies are those, which develop a sustainable and dynamic culture in the organization because culture is a core of an organization. PLM is one of a culture generating solutions, which can give the company a unique tools for Knowledge Transfer.

During the 24th CIRP Conference on Life Cycle Engineering the authors (Götzea, et al., 2017) presented a paper that investigate Life Cycle Engineering(LCE) concept from managerial point of view. They used the following definition of LCE: “engineering activities which include: the application of technological and scientific principles to the design and manufacture of products, with the goal of protecting the environment and conserving resources, while encouraging economic progress, keeping in mind the need for sustainability, and at the same time optimizing the product life cycle and minimizing pollution and waste” (Jeswiet, 2014).

On the basis of provided literature review the authors identified that this concept is mainly has engineering focus because it was originated by engineering scientists and the engineering perspective is dominating. The strong lack of Economical and managerial perspective of LCE is clear; at most, LCE activities might include several economic targets. Including of these factors can assure economic profitability and maturity of managerial methods and concepts such as Target Costing, Knowledge Management, leadership, organization and human resources issues.

Having identified this research gap about lack of managerial perspective in LCE concept, authors provided suggestions to its extension by business modeling and integration with Target Costing, with the focus on market-, customer-, and supply chain orientation.

Considering this research, research gap of Knowledge Management role in Life Cycle Engineering concept can be identified.

1.2 Knowledge management

Different forms of knowledge are considered nowadays as one of the most important organizational resources. (McCarthy, 2009) Knowledge management plays a fundamental role in the success of an organization's activities and strategies. Several knowledge sources exist. (Díaz, 2010) cites the following knowledge sources: Human resources, organizational management, technology adoption, and the business environment. The success of knowledge is a result of three factors: Changes that the organization makes to internalize this knowledge, relations among employees, and organization-driven development.

John Davis as "A set of various tools, techniques and processes that allows organization to manage the organization's intellectual resources in the most effective ways" described knowledge Management. (Davies & Duke, 2005) In other words, KM is a combination of technologies and administrative resources. Preservation of critical knowledge enables organization to systematically and accurately keep the accumulated unique knowledge and experience of experts. The introduction of knowledge management system should be initially designed at the organizational level and only afterwards - on the technological level.

Knowledge life cycle, presented in figure 4, illustrates 6 steps: Knowledge creation, Knowledge transfer

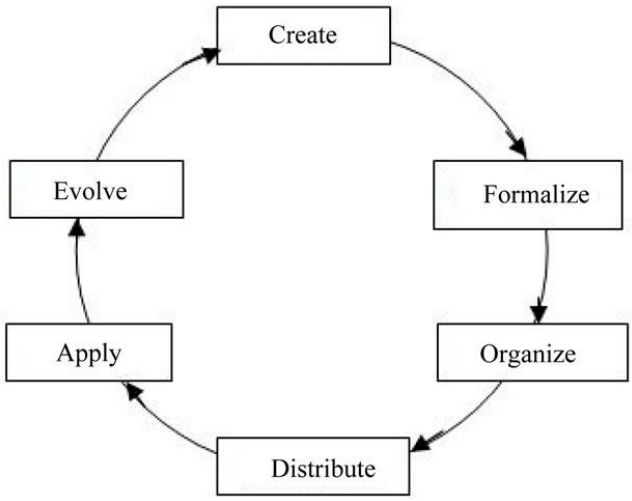

Figure 1. Knowledge life cycle

Knowledge management can be considered as a classical management cycle. Such (Tuomi, 2007) in his article presents KM in the classical cycle Goals – Implementation – Assessment (figure 1).

- Knowledge creation process consists of two main processes acquisition through external knowledge sources (literature, documents, experts, consultants, trainings etc.) and internal development of knowledge (research & development, experience, organizational learning, etc.)

- Knowledge transfer describes process of exchange, distribution of knowledge, availability for users and ensure of reuse.
- Knowledge Storage determine conservation of knowledge and avoiding knowledge loss, the selection of knowledge that is worth being conserved and use of memory media.
- Knowledge Retrieval means the identification of relevant knowledge, establishing knowledge transparency, structuring and categorization of knowledge. Retrieval is precondition for knowledge use and transfer.

In the perspective of product life cycle context the most relevant part of Knowledge Management theory to investigate is Knowledge transfer.

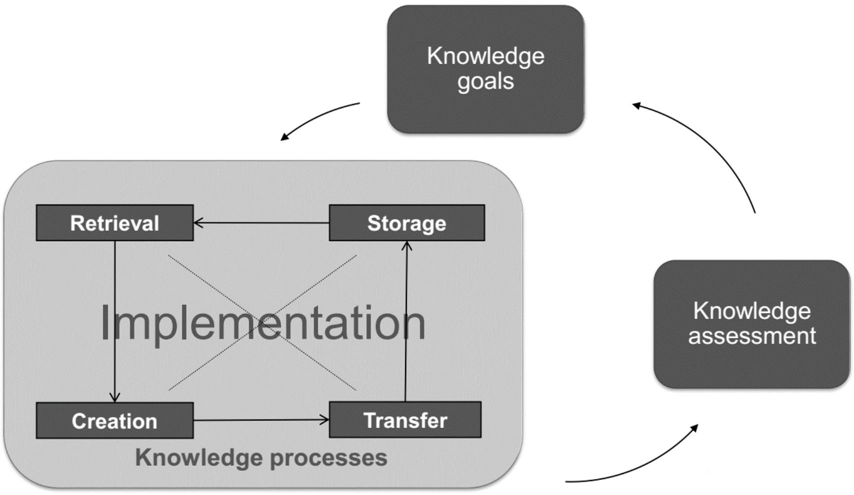

Figure 2. KM as a classical management cycle

Research Gap

Last decade Knowledge management was a very popular research topic (Nemani, 2009) Literature review provided by (Nemani, 2009) shows that previously KM research papers were mostly devoted to definition of Knowledge Management and Knowledge itself. Nowadays more and more papers directed towards solving particular business problems. Current study is not an exception. But on the basis of literature review author identified that topics related to the specifics of Knowledge transfer between product life cycle phases are not widely researched.

Considering observations made above, about lack of Knowledge Management role in Product Life Cycle Management concept, the most logical study field appears to be Knowledge Transfer. In such a way the research gap at the junction of Product life cycle management and Knowledge transfer was identified.

1.3. Knowledge transfer barriers

Organizations successful not only in making knowledge management part of their business and operational processes and work flows, but also in sustaining their investment in knowledge management, share common attributes in the areas of people, process, technology, and content. (Hosseini, 2014) These attributes should be guiding principles for KM evolution and sustainment. The figure above reflects these attributes:

- **People:** These organizations promote and sustain an environment where people share what they think others need to know because there is high trust and a partnering mindset. Leadership demands collaboration and measures performance by it.
- **Process:** Knowledge is used to make changes in the future direction of the organization. Knowledge is captured routinely as part of the operating processes of the organization and these improvements in process result in changes in the corresponding training associated with the processes.
- **Technology:** Knowledge needed is secure, searchable, accessible, and downloadable when it's needed to satisfy the knowledge seeker's need.
- **Content:** Knowledge management systems are built on the bases of content, of what it should manage. This attribute include knowledge properties, structure and taxonomy.

Current study is based on this theoretical framework. All the barriers methods and techniques are divided to 4 categories, that is presented in this study. (Hosseini, 2014)

There is study that examine the barriers classification. Author (Herrmann, 2011) suggested the following classification of Knowledge Transfer barriers, which could prevent knowledge transfer in an organization:

1. Barriers in a technology;
2. Barriers in a content;
3. Barriers in routines and procedures organization;
4. Barriers in personnel.

Herrmann (2011) claims that the first barrier means that a company sometimes does not have a hardware technology to use a software or it is cost too much then company expected to spend. He (2011) suggests using simple technology tools and trying to make a configuration of a software in a useful way. In this case, a company does not need to spend a cost to buy a new technology. Herrmann (2011) suggests another way avoiding technology barriers.

Based on literature review the author identified multiple barriers to knowledge sharing that generate high potential for failure. The list of barriers showed in table 3, section Conclusion of Chapter 1.

1.4 Classification of instruments and methods of KT

Peter Cook in his book (Cook, 2007) presented an integrated model of knowledge transfer that represent a summary of Key principles for breaking down barriers to implementing knowledge management. Knowledge transfer is a comprehensive concept and it is not enough to stay only with one strategy. Management has to take into account all cconstituents of knowledge transfer.

Making knowledge management work by learning to share knowledge, skills and experience. A comprehensive study to identify and categorize challenges related to knowledge management was conducted in (Maksimovic & Al-Ashaab, 2014). The authors have collected and processed data, obtained by interviewing a number of product development designers and engineers in large enterprise companies. Hence, the research focuses on how the key participant identify the problem of knowledge management and how it's being solved in the actual enterprise right now. As identified in the article, the key challenges of real-world knowledge are complex and versatile. Let's focus on some of the key observations, provided in the article. One of the key challenge is how to build processes to identify and capture the useful knowledge, and, most importantly, do it in such a way that the actual captured content has sufficient level of detail to convey the original ideas. To tackle this problem, techniques and processes to determine the which knowledge should be captured should be identified and applied in practice.

Another problem raised in the article (Maksimovic & Al-Ashaab, 2014) is a concern that there's just no way to properly capture the tacit knowledge. This problem is not surprising, since by its very definition, this kind of knowledge rarely allows easy capture in any simple form. The authors give a quote by an engineer who states that most of the knowledge is "inside the heads of the engineers". It seems that there's just no easy way of storing this kind of knowledge on paper or hard-drive; this kind of knowledge is naturally shared between the actual engineers within the process of doing their job and learning from experience, so improving all kinds communications between teams may help to tackle this. Communication is also one of the key challenges, as identified in the article. The authors state the root of the problem is complex department structure inside organizations and a lack of time in a presence of constant deadlines for the actual job. The area of communications may probably be improved with the changes in corporate structure and management decisions. Another key challenge is that the captured knowledge should be easy to use. E.g., participants state that they want the processes for knowledge management to be smoothly integrated into the software that they us.

People

However, all four variables are vital for a successful KM; people have an important role for knowledge management. The whole success in KM depends on the willingness of people in sharing their knowledge. In this regard, trust is a necessary element for the willingness to share knowledge. Lack of trust brings about failure in the effort of KM. It is more difficult to handle and manage KM in large organizations where it becomes harder to keep trusted relationships (Hosseini, 2014). Large organizations, which have more than 150 employees, make more efforts adapting to KM comparing to smaller organizations. Contact in large organizations is rarely face to face which is more difficult and less frequent; thus, employees are not able to share knowledge easily. In large organization, there is a weak sense of trust and connection among employees; thus, knowledge sharing needs to be facilitated.

Motivation

Motivation is one of the most difficult problems in the formation of a culture of knowledge. It responsible for the achievement of the set goals, the effectiveness of projects and knowledge management initiatives. Since it is impossible to manage knowledge directly, managers need to ensure that all the necessary conditions for the flow of knowledge management processes are created.

The important issue of knowledge transfer in this term is a lack of motivation and an unreliable source. The unreliable source has a negative impact on knowledge transfer as participants could not trust a source, so transfer knowledge from this source will be more difficult and amount of receiver could decrease. Employees might have a weak motivation to transfer and share knowledge, because they could have a fear to lost their competitive advantages among others.

As a rule, the older employees lost their curiosity and accordingly - the desire to learn something new. They have a certain number Established opinions, since they have already formed as a person. In addition, the flexibility of the brain and the susceptibility to new information with age also decreases. The process of transferring knowledge requires interpersonal interaction, which often deteriorates Psychological barriers, personal dislike. All this creates difficulties in organizing Knowledge transfer processes. (Dresvyannikov., 2016)

Another type of core activity is the development of a motivational policy and plan Promotion of their own activities. As part of the promotion, leaders are promoting their own Activity, attract attention to a new future process, advertise its benefits.

Socialization mechanisms facilitate sharing knowledge in interorganizational relationship. The Socialization may be defined as the level of interaction between, and communication of, various actors within and between the firms, which leads to the building of personal familiarity, improved communication, and problem solving (Gupta & Govindarajan, 2000)The study (Mills, 2009) shows that formal socialization mechanisms (e.g., cross-functional teams, matrix reporting structures) is not something that can improve interorganisational collaboration. However the life is tlen. It may require more subtle levers, such as informal socialization tactics. The study supports the assumption that informal socialization mechanisms (e.g., communication guidelines, social events) play an important role in facilitating interorganizational knowledge sharing.

Personal and more open communication may increase the effectiveness of the communication, improve the quality and frequency of exchange and hence, develop the interorganizational relationship. Socialization mechanisms encourage two-way information exchange, build and establish relationship trust, and enable transparency of information and cost sharing.

Corporate culture and its factors play a significant role in knowledge management. From this point of view, culture is considered as a success factor for organization to reach goals and become more competitiveness. Authors of the study (Gan, 2007) claims that there are several culture factors, which most impact on knowledge transfer processes:

- Collaboration;
- Trust;
- Learning;
- Leadership;
- Reward system

But formal socialization mechanisms help provide the structures to bring team members together, which in turn generate informal processes. They act indirectly through informal socialization to influence knowledge sharing.

This also shows that trends toward restricting informal socialization between organizations, for example buyer and suppliers, can have negative consequences.

Design – workers interaction

The dialog and interaction between designers and experienced construction professionals are highly beneficial for both sides. It helps them to come up with important implications and safety issues. The authors in the following article (Sacks, 2015) show that collaboration in Virtual reality demonstrated effective results in findings for construction safety. Virtual reality tools represent visualization of construction process at various stages through different media. Such VR consultations may conduct specific design changes that provide worker constructions' workers safety. During the study the advantages of VR tools, namely Cave Automated Virtual Environment

(CAVE) and two virtual construction sites over construction drawings: designers gain a fuller understanding of safety risks than they do from drawings, and contractors can share their experience of the site in the VR context.

However this type of communication has several drawbacks. Although VR tools enable in-depth exploration of the attitudes and behavior, it also limits the number of objectives to be considered due to absence of face-to face interaction.

Design stage is one that mostly requires effective transfer of knowledge during collaborative creative process. The definition of term design in engineering given by (Tong C, 2002) "Design is a process that constructs a description of an artifact, process, or instrument that satisfies a (possibly informal) functional specification, meets certain performance criteria and resource limitations, is realizable, and satisfies criteria such as simplicity, testability, manufacturability, and reusability''

The design is an incremental process and decisions made early in the design process have a very significant effect on Later stages. One decision made in the beginning of design may be responsible for a lot of time, energy, cost, and sustainability in the future.

The designers activities may be classified in the following way: (Pahl G, 2006) First they create concept, then embody it into prototypes, then provide detailing and specification. All this stages is accompanied by computing, drawing, and collecting the information. The bunch of essential information is accumulating throughout the design process, which could be very useful for similar design projects. The more disciplines are involved in project process, the greater need for the team to collaborate. Consequently the more data requires to be processed for well-informed thoughtout decisions. Therefore, the smart management of data, information and knowledge becomes insistent in this situation. (Senthil K. Chandrasegarana, 2012) It is important to take full account of all the details so that the design and technical activities of a set of people and organizations are closely coordinated.

Technology

In order to facilitate the capture, organization, integration, configuration control, and dissemination of design information, companies should rely on a suite of tools, which support various design processes and enable effective knowledge capture processes. These tools help to maximize knowledge capture, retention, and subsequent utilization within and between phases. Knowledge captured at an early phase may be used in a much later phase, sometimes decades later, and for reasons not initially anticipated.

The capture, transfer and management of knowledge require tools to be in place, and these tools need to be compatible with the organization's information management strategies across all departments, from design, marketing, procurement, and R&D to finance. Several examples of the tools currently used by AECL to support knowledge retention and preservation will be outlined in more detail in the following sub-sections: (Deeley & Gao, 2007)

• Equipment reliability programs
• Systematic approach to training
• Plant Configuration management
• Documented operational procedures
• Plant work management systems
• Outage planning systems
• Pre-job briefing
• Document management systems

Based on the literature we identified list of Technologies for Life cycle management. (Siemens, 2015) Life cycle stages that include engineering, construction and design are regulated with the following software solutions:

CAE systems (computer-aided engineering) for engineering analysis and calculations.

CAD (computer-aided design) The technical system intended for automation of the design process.

CAM (computer-aided manufacturing). Design of technological processes

PDM (product data management) track, control and displays data related to a particular product

SCM (supply chain management) the material flow management that implies the cost reduction

ERP (Enterprise Resource Planning) resource allocation for business processes and costs optimization

MRP, MRP II (Material Requirements Planning) applied to manufacturing process management by using scheduling, production planning, and inventory control.

SCADA (Supervisory Control And Data Acquisition) Real-time systems for collecting, processing, and displaying information about a monitoring or controlling object.

CRM (Customer Relationship Management) systems perform functions such as management of clients, analysis of business processes, improving customer service and marketing strategy

PLM system linked all the product life cycle stages, combining techniques and tools of information support to create effective knowledge management structure for multiple departments. It represents an integrative framework for various automated systems of many enterprises.

There is a study (Merminod, 2012) provided a research to test the efficiency of PLM technology. This technology was based on the case study. Author analyzed NPD process of one company before and after PLM implementation. His findings:

1) With an important codification effort, the use of PLM technology resulted in higher data and network transparency and enhanced knowledge transfer;

2) PLM served as a particularly useful tool for knowledge translation especially for boundary spanners in their work relationships.

Figure 5 organizes characteristics of software solutions, specifically PLM, CAD and ERP.

IT sub systems Pavlou and El Sawy (2006)	Domains of knowledge/ IT functionalitites	**PLM** **Design & Development Engineering**	**CAD** **Design & Development Engineering**	**ERP** **Production Sales & Services**
Organizational Memory Systems	Data uniqueness and integration	Singularity: one unique and controlling version of the product data (Grieves, 2006)	Storage of all basic parts/ components of the virtual product (Gal and al;, 2008). Examination of the fit and interferences between different parts	Reflexive conformity (Elmes and al, 2005)
	Codification/ Templates	Standardized object knowledge coding: Object structure, Object classification, Object tracking (Yi and Ming, 2010)	CAD makes implicit knowledge explicit in task based offshoring (Leonardi and Bailey, 2008)	ERP systems are inflexible once configured and implemented (Kallinikoss, 2004) However, improvised learning is possible with ERP through project leaders, power users and peers (Boudreau and Robey, 2005)
Project & Resource Management Systems	Project planning and monitoring	Project planning with links between deliverables and project milestones Dashboards	No project planning Basic dashboards	Dashboards are available for measuring business processes performance
	Workflows	Traceability: capture information and its sources (Grieves, 2006)	Making information process less costly and governance of the project more efficient (Argyres, 1999)	ERP workflow to ensure transactional business processes (Kallinikoss, 2004)
Cooperative Work Systems	Real time collaboration	Collaborative product development (Grieves, 2006) Web conferencing (Simultaneous modifications with desktop sharing)	N/A	N/A
	Virtual product visualization	Cohesion: different representations or views of product information (Grieves, 2006) PLM offers a 3D representation viewer	3D representations through CAD enable to create trading zones where communities can create knowledge (Boland and al., 2007)	N/A

Figure 3. PLM system and sub-systems properties (Merminod, 2012)

The determination of the barriers and requirement to overcome them causes a development of various digital solutions, including Cooperative Work Systems, and Project and Resource Management Systems, Organizational Memory Systems (Pavlou, 2009) , as well as Product Data Management (PDM) systems.

Cooperative Work Systems is such collaborative software that is created to help people involved in a common task to achieve their goals using technology.

Organizational Memory Systems - technology that enables to store and retrieve knowledge and information collectively.

PDM or Product Data Management is designed to improve resource and capacity planning along with optimizing ongoing allocations.

One quite important invention which integrates all these digital solutions together is Product Life cycle Management (PLM) technology, based on object storage and workflows. This system manages product and project information in all life cycle stages as it was produced and reused by individuals that perform different functions. However PLM is not universal tool, it supports mainly development tasks, and quite inefficient with creative and bad-defined research activities.

Valéry Merminod discusses how does PLM technology effective in knowledge transfer and translation in an international NPD environment. In Article (Valéry Merminod 2012) author discovers that use of PLM technology resulted a transparency of data and reduce barriers to knowledge transfer. For Boundary spanners, who perform the role of linking the organization's internal networks with external sources of information, PLM is also very useful tool for knowledge transfer in their work.

DMS - Document Management System

Documents are crucial part of codified knowledge to be well organized for easy reuse.

Documents Administration process may be divided on 3 main parts Input, Filling and output.

The whole structure of documents management process is demonstrated by table 1.

Table 1. Structure of documents management process

Document Administration					
Input		Filling		Output	
Entry	Indexing	Management	Archiving	Retrieval	Presentation
Scanning Classification Extraction	Relevant elements identification	Integrity Versioning Status management	Replication Container	precision completeness	

Management of documents through the meta-data base that contains information related to a document:

- Check-In / Check-Out– Ensuring document integrity
- Versioning– Saving changes in the document whileretaining prior versions
- Status management– E.g. access authorization depending on status
- Replication – Decentralized storage and updating
- Container – Aggregating several documents to logical units

Document system output has several challenges. Such as retrieving process has 2 main goals: to Show searching results precisely (level of relevant information in comparison with total found) and with high completeness (number of relevant data found related to amount of relevant information exist). Usually one of these goals might be achieved in prejudice of another one, appearing the goal conflict. This problem can be solved through well-thought-out search algorithms.

Another useful tool for codified knowledge is analysis of natural language through text mining. Text mining analyzes unstructured texts that are based on a natural language. For this purpose, text mining combines linguistic elements (syntax, morphology) with non-linguistic knowledge on the world (semantics). Both data mining and text mining are based on artificial intelligence and statistics, whereas text mining is exaggerated with linguistic and Semantics tools.

Functionalities of text mining:

- information extraction

- Sentiment analysis
- Summarization
- Categorize
- Clustering
- Q & A systems
- Concept linkage
- Information visualization

Approaches to knowledge representation

One of the most important conditions for efficiency of Knowledge sharing process is the use of terms that are understandable for users. The importance of a correct understanding of the terms was already noted in the last century. So the work (Alexander C., 2008) stated that each individual has its own (Internal) language to describe typical situations. 50% of the problems arise from the fact that people use the same words with different meanings, and the other 50% of the problems It arises from the fact that people use different words with the same meaning.

By providing a “common language” and creating shared understanding, socialization mechanisms facilitate the transfer of both codified and tacit knowledge between team partners. In particular, since tacit knowledge cannot be distributed in explicit form. (Davenport, 20008)
Right Knowledge representation is intendent to deal with different possibilities to describe knowledge. “Common language” is necessary for functioning knowledge management because it brings the following profit:

− General terms within a domain
− Well-defined vocabulary
− Shared understanding of the meaning of terms that are used

The common language has its certain advantages: First, it enables the access to knowledge through the integration and unification of different sources, but providing at the same time different representations and different degrees of granularity. In addition, the competently implemented system allows to achieve an adequate level of abstraction. Second, common language offers different views on knowledge: Considering from user or context perspective. In addition, it helps to focus on relevant aspects providing special terminology specific to a certain task.

A domain can be conceptualized on different levels of complexity and abstraction (Li, et al., 2009): Glossary – Taxonomy – Thesaurus – Concept – Map – Ontology – Semantic richness. These are all mechanisms are used routinely to clarify terms we use to engage and communicate understanding of any specialized domain. Figure 4 represents hierarchy of mechanisms by complexity and fullness of representation.

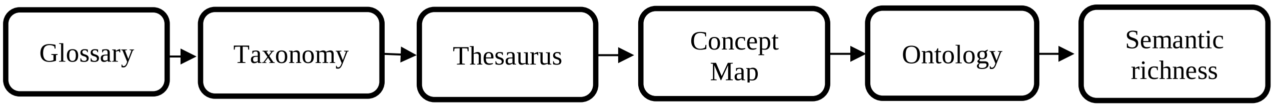

Figure 4. Classification of Knowledge Organization systems.

A glossary is a simple list of terms and corresponding explanations.

A taxonomy is a hierarchy of terms that are elements of super type-subtype relationships. No links between elements can be defined in addition to the hierarchical structure ordered in a formal way.

A thesaurus extends the model of a taxonomy by adding well-defined semantic relationships between objects: the similarity and the synonym relations. Objects with similar characteristics can be related to each other and two terms with similar meaning (synonyms) can be defined.

A concept map is a diagram that shows the links between concepts. The links between concepts can be freely chosen.

Ontology is a formal specification of a shared conceptualization of a domain of interest machine-readable or/from several individuals an ontology describes concepts (i.e., terms and their relationships) no universal, but domain-specific descriptions (i.e., for a specific ′ subject area)

Semantic approaches described below allow to ensure that participants in the process speak the same language, or at least understand each other;

The problem of mapping non-uniform ontologies describes the same subject area or related subject areas differently from the point of view of various communities.

From a semantic point of view, there are several ways of rapprochement thesauri:

• Vocabulary to match the terms

• Creation of a unified ontology.

• Industry Standards

One possible solution to provide a common language are Industry standards (eg ISO 15926 - is being developed for many years, very volumetric standard data interchange between information systems in the oil and gas sector and electric power). Originally, it was intended to be used in oil and gas industry,

But now it considered as quite universal standard, that to claim to be a comprehensive ideology for development and integration of information systems. However, in a moment it is not widely used in other industries.

Ontology mapping (Гаврилова & Кудрявцев, 2016)g is an integral part of most reconciliation tasks Ontologies such as: merging, alignment of ontologies, modification of one ontology to achieve Homogeneity with another and so on.

The problem of mapping heterogeneous ontologies is relevant from the very beginning of the use of ontologies in the creation of information systems.

The most common methods used for Problems of ontology matching:

1) Terminological analysis - comparison of the names of entities (estimate the number of coinciding Symbols, common parts of words

2) Structural analysis is implemented with the help of the following two methods:

Analysis of the internal structure - the formation of clusters of similar concepts

Analysis of external structure - Analysis of similarity in hierarchical relationships - data positions

Entities in the class hierarchy (if neighboring, upcoming or Similar) should be accompanied by other criteria. Analysis in turn can be divided into the following categories:

Analysis of cross-link similarities

Extensional analysis

3) Logical analysis - the identification of generic classes of the classes to be compared and their analysis restrictions.

For more visual work with ontologies, different methods are usually used Visualization techniques: Indented List, Node-link and Tree, Zoomable, Space-filling, Focus + Context, 3D Information Landscapes.

Problem with K leakage

When Knowledge is a common resource it increases the effectiveness of Knowledge reuse, but it might be a cause if dishonest behavior. Some employees may share the important knowledge to **competitors**. The problem is the following: the individual costs might be higher than individual profit, which can lead to reduction of organizational Knowledge underproduction.

If company have a strong strategy of codification, it increases the reusable part, but also increases risk of this important Knowledge being outflow to competitors. (IAEA, 2006)

1.5 Knowledge Transfer instruments from analysis of best practices.

In the following step in order to collect a number of instruments used for Knowledge management practices, the author examined a number of cases. All the companies considered in this analysis.

Fluor Corporation

Next observations, made based on in-depth case study on Fluor Corporation, as representative example of successful implementation of Knowledge Management System.

Fluor Corporation is a global, publicly owned engineering, procurement, construction and maintenance service (EPCM) company. Fluor mostly operates in Oil and Gas, Industrial and Infrastructure, Government, Global Services and Power segments. Their KMS became a three times winner of a Global MAKE(Most Admired Knowledge Enterprise) a prestigious award in North America. This case study investigate the dynamic success factors that allow corporation to outperform their competitors in average growth in intellectual capital and wealth creation.

The resulting solution was a web based knowledge management platform called "Knowledge OnLine". Knowledge OnLine combines social networking and document management to meet the business objectives of the firm. They realized that a global solution would require use of a strong technology platform. This platform contains a document management tool with up-to-date processes, procedures and data to ensure that all employees were using correct information and it includes people profiles and discussion forums to encourage people-to-people connections.

Siemens KMS

Before 1999 year Siemens Company didn't have any culture of sharing knowledge. Every company division managed information and knowledge flows by themselves. Mostly all information was concentrated in company headquarters in Munich and local representatives had to compete and fight in order to get access to acquired information.

In 1999 Siemens company implemented internal knowledge management system named ShareNet. (Bo Bernhard Nielsen, 2003) It had a focus on sales representatives to share best sales practices, information about customers and partners.

This system became a step to new company design; the head of company expresses the intention of reform Siemens into a knowledge-based company. In addition they wanted to make all processes run electronically, including sales, marketing, accounting and logistics.

In 2005 Siemens Building technology creates a web based KMS named References@SBT. (MÜLLER, 2007) It was developed by one person in short period of time and then expended to big system for knowledge sharing for 3000 participants. This system represents environment where employee are rewarded to share results of individual work, although this is still the main issue how to encourage experts to spend their time and contribute their crucial knowledge to the database. Now References@SBT is open for all Siemens employees and applicable for cross-divisional use. The database allows to make search of results, one of the useful functions of the search is geographical location of the results, it literally shows all the projects on Google Maps.

The goal was to make the system intuitive in use so that everybody can use it easily without reading manuals or participating in trainings. References@SBT is a next generation of communication systems in Siemens after ShareNet.

Content Structure and Taxonomy. The contributions stored in References@SBT can be divided in well structured "Knowledge References", feedbacks and spontaneous discussion postings. An unlimited number of files in any format can be attached to any contribution. Each contribution clearly displays the name of its author. This enables to build a community of experts and to identify "knowledge champions"

This paper (Bo Bernhard Nielsen, 2003) has demonstrated the role that KM governance played in ensuring the delivery of KM goals in Siemens through the lenses of authority, strategy development, organizational culture, risk management, and evaluation and measurement.

Case National Semiconductor

National Semiconductor - a multinational knowledge led company

Many barriers to knowledge sharing were identified including compliance to codified procedures, departmental conflicts, viewing knowledge sharing as a burden, variation across automated systems, conflicts caused by the internet as a knowledge source and logistics due to geographical dispersion. Knowledge-led teams overcame many of these barriers. Success bred success to the extent knowledge sharing has become a business process in the organization.

Involving engineering managers and process owners in routine spending forecasts.

Knowledge sharing crosses international boundaries. However, working across multiple time zones is not conducive to establishing informal, regular nature of communicating and sharing knowledge. This was deemed to be the prerequisite to having successful knowledge led teams in the organization. There is more scope to nurture and improve knowledge sharing between subsidiaries, although somewhat negated by the competitive spirit in which people appear to be comfortable operating under. Failure to comply with an automated knowledge based system can have many times more implications than failure to comply with a traditional manual procedure. More “checks and balances” tend to be associated with manual systems. There has not been a great deal of thought or discussion on a knowledge standardization. Adopting a standard allows one knowledge based system to be present across many tools. If no standard is present the knowledge based system may be different tool to tool.

Westinghouse

Westinghouse Electric Company is the world's leading supplier of safe and innovative nuclear technology. The company engaged in design of nuclear reactors, as well as the design and supervision of the construction of nuclear power units. The research (Batovrin & Bakhturin., 2012) that investigate Life Cycle Management of Technical Systems consider Westinghouse as another good example of company that faced the need to manage long life cycle product manufacturing process. (FORGIONNE, 2003) Describes The Intelligent Manufacturing Decision Support System (IMDS) used by Westinghouse as a knowledge-based system that captures, stores, and retrieves engineering issues for designated products. This knowledge-based system provides economic and management benefits, Such as:

- quicker flagging of engineering issues;
- complete and integrated issue searches;
- more timely and error-free engineering analyses and evaluations;
- Rapid capture, storage, and retrieval of engineering knowledge.

The IMDS architecture is based on an innovative combination of object-oriented database, graphical user interface, and expert system techniques.

The system represents concurrent engineering concept, which can be described as a systematic approach to design, engineering, and manufacturing that treats the product life cycle as an integrated and harmonious process.

Kazatomprom case study

"NAC "Kazatomprom" JSC is a national operator of the Republic of Kazakhstan on import and export of uranium, rare metals, nuclear fuel for nuclear power plants. Kazakhstan has being the world leader in extraction of natural uranium since 2009. Strategic objectives of Kazatomprom are focused on saving of the leading positions in the world market of natural uranium, maximum diversification of activity of the Company inotrope-reaction nuclear fuel cycle (NFC) by participation in foreign assets (in stages of conversion, separation of uranium isotopes, nuclear fuel production, construction of nuclear power plants), as well as diversifications into the adjacent hi-tech directions with development and use of scientific and technical capacity of the Company

LLP "Baylanys-NAK" is a corporate telecom operator and general service for groups of companies of JSC NAC Kazatomprom.

The Partnership provides communication and IT-outsourcing services to the Holding Group of companies. Technical capabilities and organization of the working process of the Partnership allow to react quickly and efficiently to the requirements of business on the part of the Customer - a group of Holding companies.

The main activity of the Partnership is to provide the Holding Company with the necessary types of communication by providing services:

Table 2. Knowledge related activities in Baylanys-NAK.

№	Service	Description
1	Basic	Corporate Email
		Corporate messenger
		Corporate portal and website
2	Advanced	Cloud document management
		Technical support and support of financial systems
3	Enhanced analytics	Integrated planning system
4	Industrial automation	CMP
		PCD
		automated process control system
		Instrument making
5	Information security	Integrated Information Security System
		Uniform IS standards
6	Telecom	Corporate network (KSPD)
		Telephony
		The Internet
		Video conferencing

As showed the document analysis, this company faces the following Problems with Knowledge Transfer.

Loss of documents of production processes (people factor, automatic system)

Do not use documents from past periods (people factor, there are no legal docs)

Adoption of managerial decisions is not always correct - the lack of complete information (human factor, lack of a database)

Plan-fact analysis and reporting system (the existing reporting system does not allow the prompt collection of data)

Duplication of information (no database, no system)

Trying to overcome named above problems, the company introduced a new methodology for document management as part of the strategic development for 2025.

This methodology covers the whole knowledge life cycle and implies a fully automated process

For each document in the information system, a passport is created that has a unique identification number and contains information about the document. It defines the category of the document: the production process, the report or the management decision. The responsible employee assigned for each document, which allows you to get information about the project that describes this document. In turn, when leaving the position, the responsible employee is obliged to transfer all information regarding the project to another person and to codify the knowledge to the maximum, as far as possible.

It also indicates the project to which this document relates and a link to the parent document. The Knowledge transfer stage are implemented through the following activities: pre-job briefing, process owners trainings, meetings, trainings of managers, self-study attestation

Assign a person responsible for the project and operational activities (document type)

Training of Heads of different levels (heads of the structural unit, top management)

Figure 8 illustrates document management system methodology.

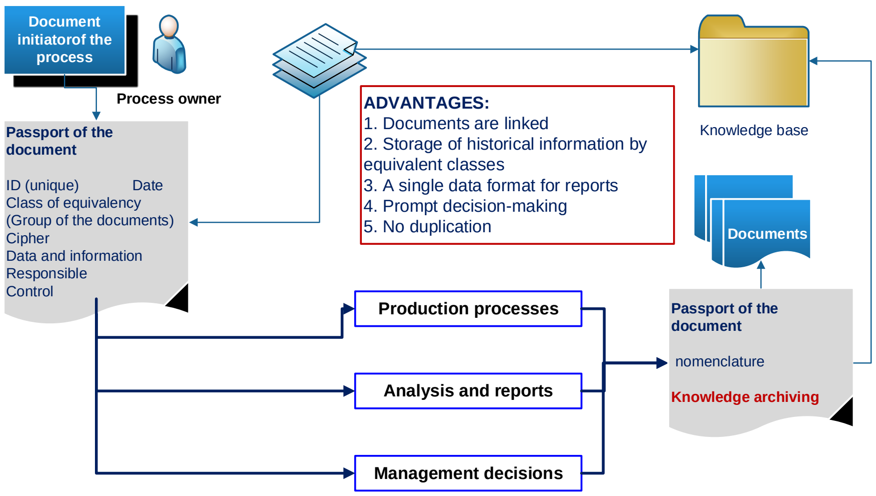

Figure 5. Kazatomprom document management methodology.

However, the scale of Kazatomprom is not so big as Rosatom, and also the range of tasks are not so wide. Moreover, as we know the instruments are highly depend on the Knowledge content and amount. Therefore, the solutions used in in Kazakhstan might not be suitable for Russian market.

Identification of needs – interview, observation, questioning

Search and retrieval – identification of knowledge sources, interview, research

Structuring – uniform format, knowledge management methodology, responsibilities, instructions and regulations

Design, creation and support – knowledge base or archive, current knowledge preservation, knowledge inventory, responsibilities

Knowledge use – passport of the document

Transfer and trainings – pre-job briefing, process owners trainings, meetings, trainings of managers, self-study attestation

Conclusion of chapter 1

Current study is based on the theoretical framework that divide Knowledge Transfer process on 4 major parts: People, Process, Technology and Content (Hosseini, 2014).

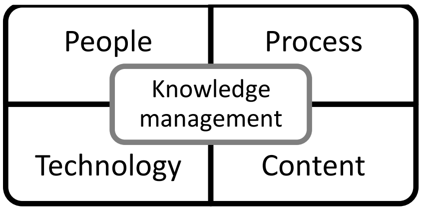

Figure 6. Theoretical framework of the study (Hosseini, 2014).

The following table 2 organized Knowledge Transfer methods and techniques found through the literature review. Table builds on sources such as (IAEA, 2016), (Deeley & Gao, 2007), (Mills, 2009), (Davenport, 20008).

Table 3. Knowledge Transfer methods and techniques.

Technology	**Processes (administrative, organizational)**	**People (personal, interpersonal)**	**Content**
Computer based training Design basis information management systems Document production and management Processes Equipment reliability programmes Information processing and management Use of intranet portals IS/IT infrastructure (e.g. ERP/EAS) Resource locators Process and procedure documentation Storytelling Training simulator programmes Use of Wikis Workforce or succession planning	Action reviews, pre/post job reviews Coaching and mentoring team learning approaches Informal staff training strategies Formal training and HR development programmes Communities of practice Use of retired or retiring specialists Systematic approach to training (SAT) Knowledge elicitation interviews Knowledge loss risk assessment and Management OPEX review and/or corrective action, processes	Decision summaries (analysis, rationale, and assumptions) Cross-functional teams, Peer assisted team visits	Concept maps, knowledge maps, ontological models Operation logs, event reports

Based on the literature review we highlighted the main barriers, which are discussed previously (Riege, 2005; McLaughli, Paton and Macbeth, 2008; Herman, 2011; Yiu and Lin, 2002). According to the proposed model of knowledge sharing and knowledge transfer barriers, we organized these barriers into three categories to a Table 3. Knowledge transfer Barriers. For our research work we will use all these factors to determine most impact obstacles on knowledge sharing and knowledge transfer in our research company.

Table 4. Knowledge transfer barriers

Technology barriers	**Organizational barriers**	**People barriers (personal, interpersonal)**	**Content barriers**
Lack of Software solutions Inappropriate software (Riege, 2005)	Lack of Leadership (Herrmann, 2011)	Self-interest (McLaughli, Paton and Macbeth , 2008)	Language differences (Paulin & Sunneson, 2012)
Different software solutions doesn't match (Herrmann, 2011)	Work distribution Weak Organization of the work (Paulin & Sunneson, 2012)	Lack of Trust (Cantoni, Bello and Frigerio, 2011; McLaughli, Paton and Macbeth; 2008)	Absence of common professional language
Immature infrastructure(Paton and Macbeth; 2008))	Weak corporate culture (Yiu and Lin, 2002)	Motivation (McLaughli, 2008)	Ontology differences (Paton and Macbeth; 2008)
Lack of Equipment, Hardware capabilities (absence of powerful computers, servers, network) *(Herman, 2011; McLaughli, Riege, 2005)*	Knowledge sharing promotion (McLaughli, 2008)	Absorptive capacity Decoding and encoding competences (Ko et al., 2005)	Unstructured information, no taxonomy (Гаврилова & Кудрявцев, 2016)
Software cost (Bello and Frigerio, 2011)	Weak reward system (McLaughli, Paton and Macbeth; 2008)	Willingness to contribute Lack of time (Riege, 2005; Yiu and Lin, 2002)	Geographical Distance (Yiu and Lin, 2002)

CHAPTER 2. RESEARCH METHODOLOGY

2.1. Methodology

The goal of this thesis is to explore knowledge transfer process throughout the life cycle phases for nuclear energy companies in Russia. This chapter describes methodology of the research, what empirical methods were used and criteria for sample choice.

2.2. Research approach

In purpose of choosing an appropriate methodology was conducted a literature review dedicated to determination of research methods were used by other authors. Article (Nemani, 2009) describes what type of research methodologies are used in conducting the research about knowledge management topics. Author claims that conducting KM research all the three major research methods, such as qualitative, quantitative and mixed methods were used proportionally evenly.

On the basis of stated problem, a qualitative approach was chosen due to specifics of research topic. These approach gives the opportunity to provide in depth analysis of the Knowledge Transfer processes in chosen industry. The other reason of choosing the qualitative research is difficulty to measure effectiveness of Knowledge management, although there were many researches that prove its advantages (Bo Bernhard Nielsen, 2003; Foss, 2004).

Case study research provide the deeper understanding of a complex issue, it provides flexibility for researcher to obtain additional information and focus on the issues that matter for the research. This type of study is also useful for testing whether developed scientific theories and models work in the real world. (Zainal, 2007)

The author uses multiple case study design for the research, because it allows to conduct detailed analysis of each case and compare the results for deep understanding of the topic. By comparing results, the common characteristics were identified. This fact prove that findings are applicable to other companies.

In this work data collection is used to explore possible solutions, create a conceptual framework and then customize this framework to a given company. (Lopes, 2016) The analysis of best Knowledge management practices was used to create a framework then tested and employ to a ROSATOM corporation.

The existing research was conducted on the basis of 2 main sources of data – primary and secondary data. Primary data is provided in a way of several semi-structured interview. Whereas secondary represents case studies, companies' reports, information from companies web-sites, conferences materials and books.

To determine how existing KMS works within the organization a series of semi-structured interview with employees from different business units was conducted. A semi-structured interview is a qualitative method; it implies that interviewer has a conversation, guided with a set of specific questions, which covers specific topics. The semi-structured interview has the advantage of gain a broader understanding of the respondent's point of view in comparison with a structured interview. At the same time, this method is more precise than unstructured interview, it is definitely more focused and thus better for addressing specific research topics. (Bryman, et al., 2011)

As the topic of the thesis was to explore three broad research questions and connected themes, it was natural to use semi-structured interviews as the main method to understand these themes deeply.

The questions of the interview were created based on the Literature review. Interview guide include questions divided by 3 categories, which were identified Based on the study (Herrmann, 2011). The author claims that success of Knowledge management practices depend on 4 major elements: people, organization (processes), technology and knowledge properties. Questions disclose the research questions. They are related to methods and techniques used for Knowledge transfer with the link to life cycle phases. Questions are aimed to determine which tools are specific for certain phases. Also they determine which barriers exist in practice in knowledge transfer in particular industry.

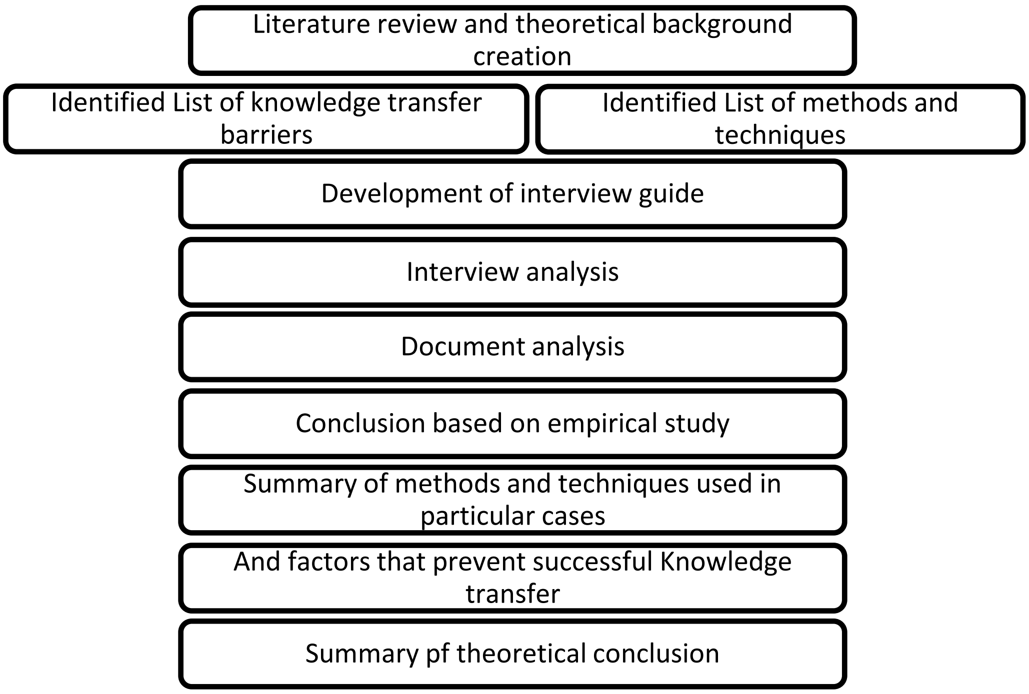

Figure 7. The stages of research procedure.

2.3. General information about the cases

Industry choice

Nuclear industry is one of the knowledge-driven industries, which successfully transform knowledge into valuable and successful competencies, products and services. It is based on the use of nuclear technology and scientific achievements of nuclear physics. Therefore, this industry is very interesting for knowledge management research. (Nemani, 2009) Long-term nuclear energy scenarios become a reason of the need to preserve and maintain accumulated knowledge in the areas of nuclear science, industry design and operating experience. (IAEA, 2006) However according to research topic, it was identified that the most suitable area of nuclear companies activities to answer research questions is nuclear power plants, because they have standardized and demonstrative life cycle.

One of the main products in nuclear industry that requires improvement of KMS efficiency are nuclear plants, which might be categorized as Complex systems engineering. Talking about knowledge transfer between product life cycle, first determine main cycles in general and in nuclear industry in particular.

- Concept of construction
- Design
- Construction work
- Commissioning
- Operation and maintenance
- Exploitation
- Decommissioning

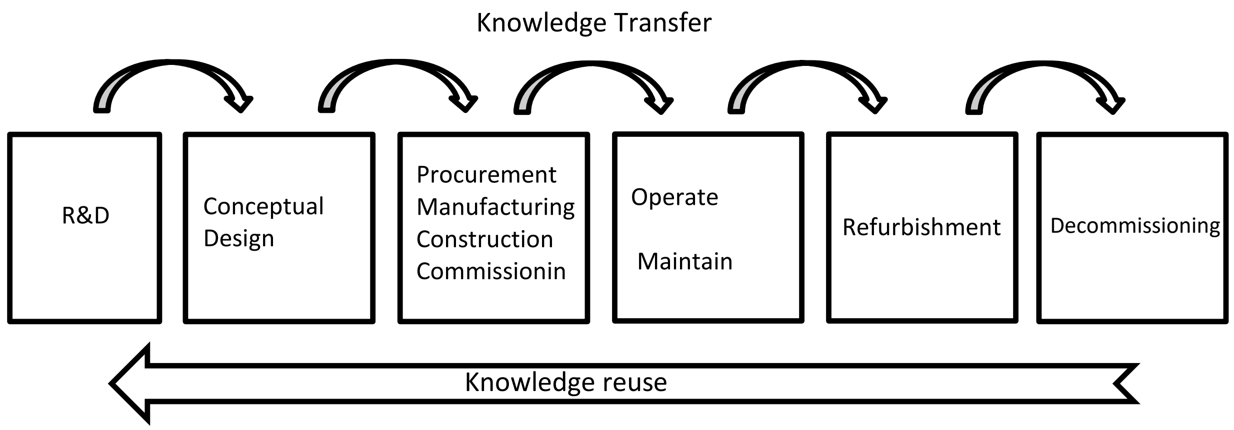

Figure 8. Life cycle view of nuclear power plant

Nuclear power plant life cycle is very long, the whole process starting from concept and ending with decommissioning might take more than 100 years. Moreover, it is still very important to keep all the knowledge and documentation about construction in order to use it for maintenance or for new plant creation.

Nuclear industry particular properties

Nuclear energy industry is a high tech company. It's effectiveness depends on experts Knowledge, therefore Knowledge management is a crucial factor for success. A lot of institutes are interested in access to wide range of nuclear Knowledge.

Usually the stakeholders of nuclear knowledge are governments, international and public organizations. R&D teams, designers and support organizations are also looking for the knowledge in terms of managing, using and developing. (IAEA, 2006)

In energy industries like Oil and other fossil foil companies evaluate effectiveness of KMS by the level of cost reduction.

For Nuclear power plant design requirements for manufacturability, construction, maintenance, operations, and for decommissioning are determined by operating and developing experience from previous projects as well as customer and supplier feedback. These requirements should be developed in the early phases of a project.

Successful implementation of tasks in a certain phase highly depends on information from previous phases and will be used in future tasks, especially in the beginning of next phases.

For each phase of the project life cycle, technical information evolves; it is created, transferred, transformed (often between individuals and organizations), and utilized in different ways and at different times

Nuclear facilities and institutes constitute a particularly challenging environment from a KP perspective. Some of the issues faced by the nuclear industry include:

- A complex technology base and infrastructure (i.e. both from a design basis perspective and from an operations and management perspective).
- Lengthy technology and facility life cycles;
- Regulatory requirements that change over time;
- Highly capital intensive assets;
- A reliance on multidisciplinary technologies and expertise;
- Competing operational objectives involving safety, economics, and production;
- Potentially high hazards that must be systematically managed to remain demonstrably and tolerably low risks;

- The ongoing need for coordination of complex physical and human systems.

Furthermore, stringent requirements for safety, environmental qualification, nuclear quality assurance, nuclear security and non-proliferation safeguards, as well as equipment/design configuration management must be met, all within the context of a regulated industry environment. For example, KP in nuclear facilities is complicated by the need to maintain knowledge over many decades and thus ensure the safety of longer term nuclear waste fuel management facilities. Another example is the need to establish and respect creative and flexible intellectual property license arrangements that allow owner–operators, design organizations, multilateral research organizations, and technical support organizations to innovate and share technical information on reactor designs (which are highly proprietary). Existing designs must be maintained, modified and adapted over time to ensure reliability and safety, to extend equipment life, or to introduce improvements offered by new technology. Thus, proprietary designs and design information must be shared amongst these parties and must evolve over time. This involves legal issues regarding knowledge utilization, transfer and generation. Finally, everything is further complicated by the threat of cyber-attacks. Knowledge flows or stores must also address the increased need for security. For these reasons, the role of KP within the nuclear industry is both particularly important and particularly challenging and underscores the need for an improved KP strategy. Nuclear KP is relevant to all nuclear organizations and supporting bodies (nuclear power plants, nuclear research institutes, research reactors, nuclear programs and research in universities, nuclear regulators, nuclear design organizations, and nuclear support service organizations).

Selection of the companies

Because of the analysis, ROSATOM State Corporation was identified as promising for answering the research questions.

Although nuclear industry in Russia represent only one State Corporation Rosatom. It represents holding, uniting more than 360 enterprises of the nuclear industry engaged in different kinds of activities, such as Nuclear energy, the extraction of nuclear raw materials, nuclear weapons, scientific research organizations, as well as the nuclear icebreaker fleet. The state corporation ROSATOM is one of the leaders in the world nuclear industry, it is the world's second-largest uranium producer and the fifth-largest in terms of production, the world's fourth largest producer of nuclear energy. Rosatom acts as a regulator in the field of nuclear energy in russia, setting standards and checking quality.

International Atomic Energy Agency presented a study, where they identified areas where knowledge and learning are the most crucial. (IAEA, 2016)

- Technical/engineering/R&D

- Program/project management
- Technical or engineering management/ leadership
- Innovations
- IT
- Field operations
- other

Based on this study we identified companies from nuclear state concern that are relevant for the Knowledge Management study. The preliminary research about nuclear industry companies proved the fact, that these particular cases represent the appropriate field to study and can give answers to the chosen research questions.

Employees of Knowledge management department and professional staff across a number of disciplines were interviewed.

Two interviewees, chosen for the dialogue, are deeply involved into the work with Knowledge. Leschenko Vladimir is a head of Knowledge Management System Department and one of its main creators, he knows its functionality, advantages and disadvantages better than anyone else. Eugeniy Khudobin is creator of Quality Management methodology, that was developed as one of the steps of reducind barriers between companies representatives of different life cycle phases and functional units as well. Third interviewee, Konstantin Shorshin is experienced representative from executive side to show how processes are organized from inside, he is able to show what problems arise in practice.

The companies, studied in the research, and interviewees are presented in Table 4.

Table 5. Companies, chosen for the case study

Company	Field of activity	Life cycle phase	Name of the interviewee	Position in the company
JSC "Science and Innovations“ Rosatom	Knowledge Management	R&D	Leschenko Vladimir Olegovich	Head of the Knowledge Management System Department
Rusatom Automated Control Systems	Enterprise architecture, business integration management.	Conceptual design, design and engineerung	Eugeniy Khudobin	Chief Operational Excellence and Product Development Officer
Rosatom	Engineering Division	design, comissioning	Konstantin	Engineer

General overview of the companies

JSC "Science and Innovations“ Rosatom

The joint-stock company "Science and Innovations" was established in 2011 to manage the activities of institutes and centers that are part of the perimeter of the Innovation Management Unit of Rosatom State Corporation. At the moment, JSC "Science and Innovation" manages 14 organizations (Росатом, 2017)

"Science and Innovations" is a company that represent first R&D life cycle phases in nuclear Life cycle demonstrated in figure 7.

The decisive pre-condition for the efficiency for any large-scale industrial enterprise lies in whether it has been fitted with modern automated information control systems. Rosatom enterprises offer comprehensive solutions for the development of highly reliable automation systems, as well as serial production, implementation and operational support during the entire life cycle of the facilities under their control.

ROSATOM knowledge management system

In this work we consider the example of Knowledge management system in state corporation “ROSATOM”. Company has already done a great job of KM system development. It continues to grow and develop. But they ran into the problem that different phases of life cycle develop separately and there is no unified system that covers all processes.

In 2011 the corporation made a decision to start working on Knowledge Management System.

The High management decided that first phase of KMS should cover only organizations that comprise in innovation management block. In future this system should be enlarged to all the Knowledge that corporation currently possesses. But first task was to overcome main problems that might appear during the system creation on local scale, on separated block. And only after full comprehension of implementation possible difficulties and particularities, the company is planning to extend System to other divisions.

This work is aimed to be a step, which would help to develop an appropriate solution. This solution should be implemented on the basis of existing Knowledge Management System by Improvement and enlargement. That will provide knowledge sharing within a subsidiary and among subsidiaries, within functional area departments, collaboration between functional area departments in a huge corporation with multinational entities.

The existing system of knowledge in Rosatom covers, however, not all phases of the life cycle. She is very well tuned to the management of scientific and technical information. And providing access to it to use information will be available to all structural units of Rosatom.

A single model of metadata has been created. A single model of metadata is the metadata about the information that is stored in all structural subdivisions of the State Corporation. This model will not only merge data into a single resource, but also simplify and speed up access to them.

Rusatom Automated Control Systems

The Consortium of Developers and Producers of NPP Automated Process Control Systems was established within the structure of the state corporation Rosatom. The Consortium is engaged in the development, production and commissioning of NPP automated process control systems, including those designed for NPPs operating in severe climatic conditions. The previous generation of automated process control systems produced in Russia are operating at the NPP units in Bushehr (Iran), Kudankulam (India), as well as in the Kalinin, Rostov, Novovoronezh, Beloyarsk and Leningrad-II etc NPPs.

In addition to automated process control systems for NPPs Rosatom enterprises produce the following products for the power industry:

automated process control systems for the mining, re-processing, and storage of gas and gas condensate; a linear remote control system to control and monitor gas pipelines and energy systems; environmental monitoring systems.

ROSATOM Design Company

The third company is also a part of Rosatom and is engaged in the design of some parts of nuclear power plants both in Russia and abroad. Компания покрывает такие стадии жизненного цикла как Conceptual Design, Design and Engineering and actively participate in design-construction interactions

CHAPTER 3. KNOWLEDGE TRANSFER RELATED TO PRODUCT LIFE CYCLE PHASES

Multiple Case analysis

The chosen research design present the analysis of details of the cases, studied by the author. The discussion is finished with cross-case table, containing the identified knowledge transfer methods and techniques in a line with barriers in chosen nuclear companies. In addition, the author provide the comparison of methods found from literature review and conclusions about the analyzed questions.

The most important discoveries are made at the intersection of scientific fields. Therefore, in production to create working, efficient systems, the employee is useful to have knowledge from neighboring stages of the life cycle, to exchange with experts.

3.1 Knowledge management practices specific for the whole organization.

The analysis shows that some moments are inherent to the whole organization and cover all the life cycle phases. Further this all particular qualities and arising problems will be considered according to (Hosseini, 2014) research framework that divide Knowledge Management practices into People, Process, Technology and Content.

Process

When there are inconsistencies in the finished products, failures in the equipment. It can be very difficult to find a reason. The most important knowledge is the root cause. In order to do this, information is needed from many people who worked on designing and maintaining this facility. To start, they need to be found, they are not always available, for example, if the object was designed many years ago. The designer could leave the company, retire and not leave the necessary information or just lost and it is unclear who participated in the project. The system of linking to the projects of each participant can help here. Secondly, there is always the risk of falsifying information when it comes to large losses. Knowledge transfer problems is one of the issues arising during the operation and developing stages of work.

The type of knowledge mostly important from Eugeniy's point of view is the root cause of appearing problems. He suppose that the best decision is to force administratively to find the cause, codify it and identify the best way to fix it.

Proceeding from this, during the interview we identified the process point of view.

Rosatom decided to implement Quality Management techniques as one of the ways to improve business processes. Evgeniy Hudobin, the author of the methodology that focuses on the implementation of major capital projects. The principle of this methodology is the verification of documentation on various criteria, such as completeness, correctness, compliance with budgetary limits, the presence or absence of litigation with the contractor, etc. Every document should be verified in order to move the project to the next phase of the life cycle, the division control the Compliance with the stages of verification.

This methodology is crucial for the following life cycle phases: Design and engineering, construction and manufacture, commission, operation and maintenance, refurbishment and decommission. R&D and conceptual design can not so well undergo the quality control.

This section also may include all types of trainings, education, development programs and HR practices. According to the internal study conducted in Rosatom, employees highlighted mentoring, in-person or virtual training and development programs for high potential employees Practices as the most effective in terms of knowledge transfer for new generation of workers. The bridge of generations is the transfer of knowledge from pensioners to youth. The succession program so far only in Atomenergomash. In order to prevent knowledge leakage the company could use *exit-interview* technique in order to preserve potential Knowledge.

Work with KMS. In each division, an employee is assigned who is responsible for implementing this system in his division. Managers of the divisions independently decide what they need to add to this system. However, at the same time this is mainly scientific and technical content, this means that other kinds of content stay uncovered.

Technology

Considering the **technological** side of Quality control process, the documents are processed with the document management system. This system has obvious drawbacks in the scale of huge government corporation, the processing of the document may take a lot of time.

Access to knowledge in an organization can take different forms. Some knowledge can be made freely available to all stuff members, but some may require access control, which is especially necessary and important in nuclear organizations. Here sometimes there are questions of secrecy, it is necessary to carefully take into account the possibility of important information leakage.

People

Motivational factor. In order to increase motivation to share Knowledge in a way of using Knowledge portal, participating in communities of practices the theory suggested several tools covering internal and external motivation. (Mills, 2009) External motivation in its tern divided into Material and non-material encouragement.

Vladimir Leshenko, one of the creators of Knowledge Management system in Rosatom assured that the best motivation is convenience and functionality of the system. Functions of the system should become necessary condition for work process, or at least to make this process easier.

Motivation is psychological factor; therefore, it requires the appropriate approach, for example to use different techniques for representatives of generations X, Y and Z.

All interviewees agreed that the best motivation is to add knowledge transfer to the duties of employees. This should be an integral part of the business process. With the help of regulatory documents, so that the employee does not spend extra time, and this happened by itself.

Content

While creating Knowledge management system, "Science and Innovation" faced with problem of organizing accumulated data. When knowledge was codified, it should be preserved and structured in a way it could be easily reached. The task to organize all the data is quite complicated especially in condition of scattered, heterogeneous data to be stored. For information stored in databases, database design should consider ease of retrieval in the future using metadata, thesauri, taxonomies, ontology, etc. Integrated information systems provide interoperability of different knowledge formats, including text, data, drawings, videos, and/or 3-D models. Author, release number, date of production, subject and/or keywords, can classify the information. Computer aided metadata creation tools can also be used to create metadata automatically for knowledge resources.

Vladimir mentioned, that they faced with the problem because traditionally, the blocks that are planned to be merged into a single system have evolved separately, the processes it them are regulated by different regulatory and normative documents in Russia and abroad. Due to different expertise, different technologies of Life Cycle Management.

The main task is to study the regulatory, legal, and technical base and link to the management technology of the Product LC. Methodological approaches to the convergence of thesauri.

The other problem on the agenda is harmonization of the regulatory and legal framework, which includes both external and internal documents. Such as the laws of the federation, regulatory and technical documents, design documentation, internal regulations relevant to internal business processes. Different types of documents and different practices of their use cover different stages of the life cycle, such as engineering, construction, operation, R&D. The documents are expected to be in a common logic and changes in one document causes changes in other ones that depend on the document or linked with it. But in reality, the existing system does not cover all stages due to the complexity of integrating different formats of system use. Because the work at each stage has its own specialties, the system exists locally in each stage. There is lack of administrative mechanisms that create a common culture of Knowledge share. link all the divisions and organizations .

The following tasks are still relevant and no solution found yet:

Common semantic model development and tacsonomy of data processing in several of ROSATOM. Creation of single comprehensive model of documents management.

3.2 R&D specific

We can distinguish several practices that is specific for R&D life cycle phase. From the process point of view, these are internal and international conferences, interaction with universities.

Work in such a technically complex industry as nuclear energy involves buying Western technologies to improve production processes. However, sometimes it turns out that the purchased technology has already been invented by the corporation earlier, and is simply lost in paper archives. This leads us to the next problem of R&D life cycle phase - the huge amount of paper archives, lots of them have the unknown content, might contain duplicates. This problem requires big amount of work of identifying crucial and valuable information and convert into a digital format. Digitized scientific reports or scientific libraries - this is not knowledge, they need to be prepared and placed in electronic form, so that they are understandable to the user and convenient. There is a system of antiplagiarism, which showed very good results and reduced the number of plagiarism to an average of 10%. Taking into account references to literature, it turns out that now scientists provide almost completely unique text of research.

Management of R&D knowledge include the commercialization of intangible assets, conversion of the scientific knowledge into final product to be sold. This practice borrowed from the best technology companies like IBM, General Electric. This once again leads us to the idea of the need for the digitization and structuring of previously accumulated knowledge.

3.3 Design – construction specific

This part of the study based on case of one of the design company of ROSATOM. The interviewee Konstantin worked as an engineer in the company creating Design of some parts for Nuclear Power plant for 12 years. He mentioned that The Knowledge transfer problems are crucial nowadays for the company.

Process

Many problems arises because the period of Nuclear power plant exploitation is very long. After 20 years it is hard to find technical documentation related to the object. “We had a case, it was necessary to find the drawings of the reactor in order to conduct repair works. Occasionally, we found out that one employee who had already retired somehow left copies of the blueprints. We were compelled to invite him on special terms to lead the reconstruction process.” Here we come up with necessity to use retired or retiring specialists.

Wise distribution of experienced specialists facilitates the transfer of necessary knowledge about the features of construction to employees in future projects. For this purposes the company

Konstantin used to work practice the following scheme: They try to hire team that already had experience in similar projects that was engaged in commissioning a similar facility. Even if on the first object they were the level of masters, on the second project we can already make them to manage the works.

Interviewee find important organization of procedures of managing changes in technical documentation. This is always a big problem, always works poorly. We had project with Chinese company. The spent 5 years to adjust the process of documentation changes.

The importance of Transfer of Knowledge between designers was mentioned in literature review (Gupta & Govindarajan, 2000). Designers and engineers are interested in the correct implementation of their blueprints, and the other way around the construction workers may bring very useful insights in the object creation.

Konstantin mentioned tool, used for this purposes - *author supervision* that can be described as "The control of the person who carried out the preparation of project documentation, for compliance with the requirements of the project documentation" (Госкомитет, 1999).

Technology

The company made an attempt to implement several software solutions for Life cycle management.

They implemented PLM system and tried to work with it for some time. Although it appears, that it doesn't fulfill our requirements and doesn't work properly in our conditions.

As Mentioned Evgeniy from Rusatom Automated Control Systems, program and project management (PMBOK, P2M, IPMA) appears to be adequate tool for construction projects management. Product and brand portfolio management, product and service life cycle management. E2E business process, organizational and financial structure design and implementation. E2E asset management: audit and systematization based on unified registry practices, cross-domain accounting integration; unified due diligence, bargaining and deal monitoring procedures design and implementation.

3.4 Construction – Operation specifics

Process

At the stage of commissioning, it is very important to periodically monitor the construction of the building by those people who will use it in the future. More codification of operational knowledge is also needed as well as education of specialists in briefing and commissioning.

When an object is already finished so called *Acceptance testing* are used for successful transfer of the project to the next phase of knowledge transfer. As a rule it is a test conducted to determine if the requirements of a specification or contract are met. Usually it involve physical or performance tests. All the actual results should be recorded, actual and expected results are compared, and test results are determined. On the basis of the test results construction team decided to pass the object or make changes.

Content

Tables with data are badly perceived by people who will use the product (customers, employees of operational phase). *Visualization* is absolutely important for Customers, who are asking about variety of data and processes management issues, but nothing can excite them more than 3D visualization the products – cars, airplane interior, engine, fashion collection, etc.

3.5 Discussion of the findings

The idea of developing tools for Knowledge Management comes from very common problems like knowledge leakage, searching and waiting for data, data translation, working with wrong data and reinvention of the existing knowledge.

Implemented Knowledge Management System is very helpful tool, although at the moment it covers only scientific and technical data. There is still a huge amount of necessary information to be transferred between product life cycle phases. In this regard, such knowledge is transferred through other tools and processes, or because the necessary methods are not available, then knowledge is not transferred and cause problems or inefficiencies in the work process. Therefore we should consider knowledge transfer process as a complex concept far beyond Knowledge management system as IT system. Knowledge created and shared through lots of the activities.

The example of the companies in the Rosatom corporation once again proved that knowledge management is a very important aspect for increasing the profitability of the business. Knowledge sharing and knowledge transfer play an important role in knowledge management and allow employees exchanging their perspectives, thinking, and ideas, and thus create a strong relationship between each other.

JSC "Science and Innovations“ responsible for managing all R&D related initiatives of Rosatom shows that it is possible to use knowledge as a product that could be commercialized and not only used for internal company purposes.

Technology

Speaking about possible software solutions, although the knowledge management system has been effectively implemented in the corporation's production process, it covers only a portion of the required knowledge to be transferred. Basically, it covers scientific technical content. At the same time interviewers from other departments admit that although the system looks promising, at this stage of its development it is not a tool that one would like to see as a tool for managing knowledge flows between the stages of the product life cycle. Although all the interviewees seems to be optimistic about system's future.

According to the review of literature and the study of the best practices of other companies, PLM solutions as a knowledge management system play a significant role.

Although Konstantin, who directly worked as a designer and during his work was an attempt to implement this decision in the process, said that in their case this system did not meet the needs. But we can not draw conclusions about its inefficiency. Firstly, there are a lot of them from different manufacturers, with different functions, in the second because, like any IT system, it has to be adjusted to the current process. The core components of a PLM system are not limited to those of today's state-of-the-art solutions and as PLM solutions gain more maturity, the necessary and sufficient elements of the system will become clear.

Organizational and administrative

We consider people who are engaged in information processing and decision-making Knowledge of who does what, how those processes are processed, what a person does. To be integrated into the processes for the beginner. Every employee is a monopoly owner of his knowledge.

In any case, despite the various technological solutions, the main method for transferring knowledge is and will remain various types of training. The main methods selected from the empirical stage will be mentoring, pre-job briefing and development programs.

Personal

One of the identified problem was lack of time for people to contribute to the web-based knowledge portal.

We consider that trust does not appear from nowhere and it requires a lot of time to build strong relationships between employees. We think that other barriers, quarrels and raised voices, connect with the previous barriers. From our point of view, as the employees think that they have problems with work procedures and work distributions and sometimes they need to do another employee' work, the participants might have quarrels because of these reasons. Speaking about last personal barrier, the language factor, for one employee it is hard to share and to transfer knowledge and to operate with documents in different language, but for most of the employees there is no problem to do it.

To summarize, we could suggests the research company and managers to pay more attention to current problems, to provide often meetings with employees, where they could discuss current situations, to show trusting relationships to them, to pay attention to employees' perspectives and thoughts and to apply different factors of motivations. Thus, we believe that our research could help the research company and managers to improve employees' and managers' works, to share and to transfer knowledge in an effective way, thus the company could obtain more profits and become more competitive.

Content, knowledge properties

Another problem is how to organize all the information. It should be in one logic. Development of Unified methodology of management of the document. Documents must be in a single system and a single logic, a change in one document should lead to automatic updating of the data in the other associated with it. Methodological approaches to the convergence of thesauri. Move process of business process scanning to employees, not only to managers. They may have insights that manager couldn't notice.

Case study shows that Rosatom overcome this problem by developing a single classifier and a single thesaurus, which allow you to overcome the problems of misunderstanding in connection with different specific work. However in reality this system doesn't perform the stated goal to link the separate divisions into a comprehensive knowledge network.

Finalization

All the findings of the works are summarized and structured in the table (APPENDIX 2). This table contains methods used for knowledge transfer between life cycle phases. However, we shouldn't forget about preservation of knowledge for future projects. The transfer of accumulated knowledge for future projects should accompany all stages of the life cycle.

This study identified plenty of methods of Knowledge transfer. But how to choose the best one, what focus should take the company that doesn't have Knowledge management practices yet. Thanks to a survey conducted in Rosatom, the most effective methods of transferring critical knowledge:

- Mentoring
- In-person or virtual training
- Technical networks
- Program high potential employees
- Communities of practice
- Technical conferences and forums
- Expertise location system/ approach
- Competency management program

- Libraries and central repositories
- Dual career tracks

CONCLUSION

In this paper, theoretical information on knowledge transfer in the nuclear sector was generalized and structured. In order to find out which of the theoretical methods for knowledge transfer are applicable in practice, semi-structured interviews were conducted as a part of multiple case studies. Three companies were chosen for the case studies, each of them is a part of Rosatom state corporation, the only representative of nuclear industry in Russia. Each of the interviewed companies covers a different phase of product life cycle, highlighting the knowledge transfer concept from different points of views. The research investigated various methods that are both specific for each of life cycle phases and generally applicable to all of them. Our findings are summarized and structured in the table (Appendix 2).

Our findings show that not all barriers and methods revealed in the theory are relevant in practice in a setting of our particular companies. For example, web based knowledge portal, a method that is described in almost every paper related to knowledge management suitable mostly for R&D and Design phases, and doesn't play a significant role in stages of construction, operation and maintenance. Another example is PLM (Product Life cycle Management), which is claimed to be an effective tool for managing knowledge throughout all the life cycle phases in the literature. Nevertheless, we reported that PLM had not worked for interviewed companies due to difficulties of implementation and peculiarities of their manufacturing process. Respondents noted that their main problem is a large disparity between stages of a life cycle. Many processes have different standards, regulated by different normative documents, and different management technologies. This is their main barrier to the transfer of knowledge between life cycle phases.

All the findings of the study are consistent with the known theoretical framework (Hosseini, 2014).

Limitations

Our research aims to cover knowledge management in all phases of product life cycle. However, there are still stages missing from the interviews. Notably, Refurbishment and Decommission were not covered during the interviews. In the course of this research, only managers were interviewed, therefore results of this study do not include employees' perspective. Thus, the results of research could be different and show some new aspects about knowledge transfer and knowledge sharing.

Suggestions for further research

This research focuses solely on the qualitative analysis and describes how the knowledge transfer process is organized. It would be interesting to conduct a research on the topic using quantitative methods to investigate efficiency of identified methods and techniques. It would also be interesting to compare results of our findings in the nuclear sector with the companies from other areas and companies having different life cycle phases. Further research on the reasons of a failure to integrate PLM in the interviewed companies would also be an interesting topic to pursue.

LIST OF REFERENCES

1. Alexander C., 2008. TheTimeless Way of Building.. *Oxford University Press, New York.*
2. Alexander Smirnov, n.d. *Multi-Model Ontology Matching for Knowledge Management in Production Networks.* Saint-Petersburg, s.n.
3. Bo Bernhard Nielsen, F. C., 2003. Siemens ShareNet: knowledge management in practice. *Business Strategy Review, 2003, Volume 14 Issue 2,* pp. 33-40.
4. Bryman, A., Bell, E., Mills, A. J. & Yue, A. R., 2011. *Business Research Methods. First Canadian Edition.,* Toronto: Oxford University Press..
5. Cook, P., 2007. *Making knowledge management work by learning to share knowledge, skills and experience,* s.l.: Gower.
6. Davenport, T. a. P. L., 20008. Working Knowledge.. *Harvard Business School Press..*
7. Davies, J. & Duke, A., 2005. "Next generation knowledge access". *Journal of Knowledge Management,* 5(4), pp. 64-84.
8. Deeley, C. & Gao, M., 2007. *Knowledge sharing in interorganizational product development teams: The effect of formal and informal socialization mechanisms.* s.l., s.n.
9. Díaz, L., 2010. Gestión del conocimiento y del capital intelectual: Una forma de migrar hacia empresas innovadoras, productivas y competitivas.
10. Euzenat J., S. P., 2013. Ontology Matching. *Springer,* p. 511.
11. Folan, H. C. &. P., 2012. Product life cycle: the evolution of a paradigm and literature review from 1950–2009. *Production Planning & Control,* pp. 641-662.
12. FORGIONNE, G. A., 2003. MDS: A Knowledge-Based System to Support Concurrent Engineering at Westinghouse. *Systems With Applications. Pergamon Press Ltd.,* Volume 6, pp. 193-202.
13. Foss, N. P. T., 2004. Organising knowledge Processes in the Multinational Corporation. *Journal of International Business Studies,* pp. 340-349.
14. Gan, G. R. C. a. G. R., 2007. The Effects of Culture on Knowledge Management Practice: a Qualitative Case Study of MSC Status Company.. *Kajian Malaysia, 24* , pp. 97- 128.
15. Götzea, U., Peçasb, P. & Schmidta, A., 2017. Life Cycle Engineering and Management – Fostering the Managementorientation of Life Cycle Engineering Activities. *Procedia CIRP* , Volume 61, p. 134 – 139.
16. Gupta, A. a. G. V., 2000. Knowledge Flows within Multinational Corporations.. *Strategic Management Journal 21,* p. 473–496.
17. Gupta, A. & Govindarajan, V., 2000. Knowledge Flows within Multinational Corporations.. *Strategic Management Journal,* Volume 21, p. 473–496..

18. Herrmann, N., 2011. "Barriers for an efficient Management of Knowledge. Experiences from a Southern African Organization.". *Open Journal of Knowledge Management*, Volume 3, pp. 1-15.
19. Hosseini, M. R., 2014. The Impact of People, Process and Technology on Knowledge Management. *European Journal of Business and Management.*
20. Hu, W., 208. Matching large ontologies: A divide-and- conquer approach. *Data and Knowledge Engineering Vol.67 no 1,* pp. pp. 140 - 160.
21. I. Cruz, F. A. C. S., 2009. *Efficient Selection of Mappings and Automatic Quality-driven Combination of Matching Methods.* Washington DC. , s.n., pp. 1-12.
22. IAEA, 2006. *RISK MANAGEMENT OF KNOWLEDGE LOSS IN NUCLEAR INDUSTRY ORGANIZATIONS I,* VIENNA: NTERNATIONAL ATOMIC ENERGY AGENCY.
23. IAEA, 2016. Knowledge Management and Its Implementation in Nuclear Organizations. *Nuclear Energy Series No. NG-T-6.10.*
24. Jeswiet, J., 2014. Life cycle engineering: A definition.. In: *CIRP Encyclopedia of Production Engineering.* s.l.:s.n., pp. 757-758.
25. Lawson, B., 2009. *Product developement and Management Assosiation.* s.l., s.n., pp. 156-172.
26. Li, J., Tang, J., Li, Y. & Luo, Q., 2009. Li, J. Rimom: A Dynamic Multistrategy Ontology Alignment Framework. *IEEE Transactoins on Knowledge and Data Engineering. Vol. 21, no. 8.*, pp. 1218-1232.
27. Lopes, I. T., 2016. Research methods and methodology towards knowledge creation. *Contaduría y Administración,* pp. 9-30.
28. Maksimovic, M. & Al-Ashaab, A., 2014. Industrial challenges in managing product development knowledge. *Knowledge-Based Systems*.
29. McCarthy, G., 2009. *KNOWLEDGE MANAGEMENT WITHIN A MULTINATIONAL KNOWLEDGE LED COMPANY.* s.l.:s.n.
30. McLaughli, S. P. R. a. M. D., 2008. "Barrier Impact on Organizational Learning with Complex Organization.". *Journal of Knowledge Management,* 12(2), pp. 107-123.
31. Merminod, V. ,. R. F., 2012. How does PLM technology support knowledge transfer and translation in new product development? Transparency and boundary spanners in an international. *Information and Organization,* pp. 295-322.
32. Mills, A. J., 2009. Knowledge sharing in interorganizational product development teams: The effect of formal and informal socialization mechanisms (Conference Paper). *Journal of product Innovation Management.*

33. MÜLLER, J., 2007. *GLOBAL EXCHANGE OF KNOWLEDGE AND BEST-PRACTICES IN SIEMENS BUILDING TECHNOLOGIES WITH 'REFERENCES@SBT'.* Vienna, Austria, s.n.
34. Nagy, M., 2010. Towards an automatic semantic data integration: Multi-agent framework approach. *Semantic Web,* pp. pp 107 - 134.
35. Nemani, R., 2009. Research Methodologies used in Knowledge Management. *Association for Information Systems Electronic Library (AISeL),* Issue 5.
36. Pahl G, B. W., 2006. Engineering design: a systematic approach.. *Springer.*
37. Paulin, D. & Sunneson, K., 2012. "Knowledge Transfer, Knowledge Sharing and Knowledge Barriers – Three Blurry Terms in KM.". *The Electronic Journal of Knowledge Management,* 10(1), pp. 81-91.
38. Pavlou, P. A. &. E. S. O., 2009. From IT leveraging competence to competitive advantage in turbulent environments: The case of new product development.. *Information Systems Research, 17(3),* p. 198–230.
39. Sacks, R., 2015. Safety by design: dialogues between designers and builders using virtual reality. *Construction Management and Economics* , pp. 55-72.
40. Senthil K. Chandrasegarana, ,. K. R., 2012. The evolution, challenges, and future of knowledge representation in product design systema. *Computer-Aided Design.*
41. Siemens, 2015. *PLM Software.* [Online] Available at: http://www.plm.automation.siemens.com/pl_pl/Images/8084_tcm801-4182.pdf
[Accessed 2017].
42. Tong C, S. R., 2002. Artificial intelligence in engineering design. *Academic Press vol.1.,* p. (Chap. Introduction).
43. Tuomi, I., 2007. “Data is More than Knowledge: Implications of the Reversed Knowledge Hierarchy for Knowledge Management and Organizational Memory.”. *Journal of Management Information Systems,* 16(3), pp. 107-121.
44. V. Bui, R. V. J. L., 2012. A Body Sensor Platform for Concurrent Applications. *IEEE Int. Conf. on Consumer Electronics. ,* pp. Pp. 38-42.
45. Valéry Merminod, F. R., 2012. How does PLM technology support knowledge transfer and translation in new product development? Transparency and boundary spanners in an international context. *Information and Organization,* pp. 295-322.
46. Wolf, P., 2011. *Participation in intra-firm communities of practice: A case study from the automotive industry.* Zurich, s.n., p. Journal of knowledge Management.
47. Zainal, Z., 2007. "Case study as a research method". *Jurnal Kemanusiaan,* Volume 9.

48. А.В., Я., 2016. Развитие процессов управления знаниями на примере внутрикорпоративных баз данных.
49. Айснер, Л., 2015. Развитие крос-культурных коммуникативных компетенций в условиях глобализации экономики. *Вестний Сибирской академии.*
50. Батоврин, В. & Бахтурин., Д., 2012. Управление жизненным циклом технических систем. *Промышленный и технологический форсайт Российской Федерации.*
51. В. А. Першуков, Д. М., 2012. *Росатом делиться знаниями. Knowledge management высокотехнологичных компаниях.* Москва: НИУ ВШЭ.
52. Гаврилова, Т. & Кудрявцев, Д., 2016. *Инженерия знаний. Можели и методы: Учебник.* Санкт-Петербург: "Лань".
53. Госкомитет, Г. К. Р. Ф. П. А. П., 1999. *"Авторский надзор за строительством зданий и сооружений".* s.l.:s.n.
54. Дресвянников., В., 2016. *Управление знаниями организации: учебное пособие.* Москва: КНОРУС.
55. Росатом, 2017. *Росатом. Наука и Инновации.* [Online] Available at: http://niirosatom.ru/o-kompanii/ [Accessed 2017].

APPENDIX 1

Interview guide

1. What is your name? Company name? Field of company activity?
2. What life cycle phase company operates?
3. What kinds of knowledge are mostly crucial in your company? What knowledge is most often shared between stages of the life cycle?
4. Who are usually participants in the knowledge exchange at different stages of the life cycle in your company (engineers, workers, managers)?
5. What goals do you set for yourself in improving the transfer of knowledge (improve the speed of the project, reduce risks, increase the economic efficiency of projects)?

The following questions are based on Table 1, which presents the various methods and technologies that can be used in knowledge transfer, and Table 2, which lists possible barriers.

a) Processes

6. During which processes knowledge transfer take place (work organization, trainings)?
7. What processes allows effectively transfer knowledge within your company, and which are not? Why?
8. What organizational barriers arise in the exchange? How do they influence the transfer of knowledge?

b) Technological

9. What technology tools do you use to share/transfer knowledge?
10. Which technological solutions are used for Life cycle management (PLM, CAD, ERP)? Do they have knowledge transfer functions?
11. What are advantages and disadvantages of these solutions? What problems do you have with using the technology tools?
12. How do you overcome problems with different technological versions and solution between functions?

c) Individual

13. What personal qualities of employees influence the process of knowledge sharing?

13. How do you overcome problems with linguistic, cultural differences?

14. Do the following factors affect the transfer of knowledge: motivation, reputation, the ability of an employee to understand clearly and to perceive new information?

15. Do you have incentives for the initiative to share knowledge?

D) Properties of knowledge

16. How do the forms of presentation of transmitted information affect?

17. Different phases of the life cycle often operate in isolation, regulated by different normative and legal documents. How does this affect the transfer of knowledge?

18. In this regard, are there standards, a common taxonomy of knowledge representation?

19. Employees of different phases can use different terminology. Are there any difficulties in this regard? How do you solve this problem?

20. Would you like to add something?

APPENDIX 2

Framework organizes all methods and techniques used in Knowledge transfer between product life cycle phases in nuclear industry

<table>
<tr><th>LC phases
methods</th><th>R&D</th><th>Conceptual Design</th><th>Design and Engineering</th><th>Manufacturing Construction
Commissioning</th><th>Operate & Maintain</th><th>Refurbishment
Decommission</th></tr>
<tr><td rowspan="4">Managerial Organizational and administrative</td><td>Conferences</td><td>Design basis information (changes) management</td><td>Author supervision →
experience factory</td><td>Cross-functional teams Peer assisted team visits Project management</td><td>Testing, Acceptance tests, customer feedback</td><td>Use of retired or retiring specialists Experimental demonstration centers</td></tr>
<tr><td colspan="3">Bank of ideas, licensing practices</td><td colspan="3">Operation logs, event reports, Use of retired or retiring specialists, Action reviews, pre/post job reviews</td></tr>
<tr><td colspan="6">Formal training and HR development programs, distance learning systems, Adaptation of new employees, coaching and mentoring, exit interview</td></tr>
<tr><td colspan="6">exchange of tacit/implicit knowledge: interviews, questionnaires, conferences, meetings, mentoring, training, communities of practice
Knowledge loss risk assessment and management</td></tr>
<tr><td rowspan="6">Technological and informational</td><td rowspan="3">Intellectual property databases</td><td rowspan="2">CAD</td><td rowspan="2">CAE</td><td rowspan="2">CAM
SCM (supply chain)
MRP, MRP II</td><td>SCADA, CRM
Enterprise asset management EAM
Visualization tools</td><td></td></tr>
<tr><td colspan="2">Equipment reliability programs</td></tr>
<tr><td colspan="5">ERP(Enterprise Resource Planning), Enterprise Application Search (EAS), Decision support systems, (Product Life cycle Management) PLM</td></tr>
<tr><td colspan="6">Document Management system, Knowledge databases, Historical data systems, DBMS, OLAP</td></tr>
<tr><td colspan="6">Knowledge management tools: Expert or people Directory, Knowledge portal + Version Control System (VCS)
Knowledge Repository, Wikis, Exemplars and Templates, Computer based training (CBT)</td></tr>
<tr><td colspan="6">Communication tools(Mail; E-mail; Internet/intranet; E-learning; Simulation software)</td></tr>
<tr><td>Personal</td><td colspan="6">Motivation to share, reward systems, leadership, Informal staff training strategies. HR practices. KMS promotion</td></tr>
<tr><td>Content</td><td colspan="6">Industry dictionary, thesaurus, taxonomy, ontology mapping; Concept maps, knowledge maps, ontological models</td></tr>
</table>