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Development and Implementation of Enterprise Information Management Systems for Interoperability

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been previously submitted for doctoral or equivalent academic degree.

Rivo Lemmik

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Ettevõtte infohaldussüsteemide arendamine ja juurutamine koostalitlusvõime jaoks

RIVO LEMMIK

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List of Publications

The present PhD thesis is based on the following publications, presented in Appendix and referred to in the text as “Paper I”, “Paper II”, “Paper III” and “Paper IV”.

I. **Lemmik, R**., Otto, T., Küttner, R. (2014). Knowledge management systems for service desk environment. *Proceedings of the 9th International Conference of DAAAM Baltic Industrial Engineering*, 139−144.

II. **Lemmik, R**., Karjust, K., Otto, T. (2014). Fault tolerance in integration interfaces of business software. *International Journal of Scientific Knowledge (Computing and Information Technology) IJSK*, 5(2), 35−43.

III. **Lemmik, R**., Karjust, K. (2012). Interoperability between different interest groups - practice portal case study. *Proceedings of the 8th International Conference of DAAAM Baltic Industrial Engineering*, 169−174.

IV. Sutanto, J., Liu, Y., Grigore, M., **Lemmik, R.** (2018). Does knowledge retrieval improves work efficiency? An investigation under multiple systems use. *International Journal of Information Management*, 40, 42−53. https://doi.org/10.1016/j.ijinfomgt.2018.01.009

Author's Contribution to the Publications

The author has contributed to the papers in this thesis as follows:

I. Paper describes preparation of Knowledge Management System survey. Author worked with sources for survey constructs. According to keyword search matched over 100 papers, full text downloaded 48 papers, constructs are based directly on 16 papers.

II. Paper describes fault tolerance principles for integration interfaces. Author built and analyzed prototype solution as a case study.

III. Paper describes testing and implementation of products and services. Author built and analyzed prototype solution as a case study.

IV. Paper describes Knowledge Management System survey publishing and results. The paper was published in cooperation with a foreign research group where the author participated within one academic semester. Author coordinated communication and organizational issues with the company where the survey was conducted. The author participated in all focus group interviews and contributed to survey questionnaire preparation. Author organized survey web publishing and collected all the filled questionnaires.

Introduction

Agility and flexibility that are needed in today's production can be achieved by integrating workplaces with information management processes and systems inside a company as well as creating networks of companies. The network is formed by things/objects having identities, virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate with the users (Vaidya et al., 2014). Moreover, by utilizing advanced information analytics, networked machines will be able to perform more efficiently, and such trend is transforming manufacturing industry to the next generation, namely Industry 4.0 (Lee et al., 2015). Enterprise collaboration becomes increasingly important because of globalized economic context, where an enterprise often interoperates at the same time with many different heterogeneous partners having different technologies, semantics, methods of work and organizations (Tu et al., 2016).

Moving beyond people to machines and systems, interoperability is becoming a key factor of success in all domains, in particular, interoperability has become a challenge for enterprises, to exploit market opportunities, to meet their objectives of cooperation or simply to survive in a growing competitive world where the networked enterprise is becoming a standard (Guédria et al., 2015). Just as the internet transformed how humans interact with one another, cyber-physical systems will transform how we interact with the physical world around us and how we will address the many grand challenges that await in the economically vital domains of transportation, health-care, manufacturing, agriculture, energy, defense, aerospace, and buildings (Sitton et al., 2016).

Most of the existing interoperability solutions propose integrated or unified approaches, which are unsatisfactory to dynamic networking enterprises (Tu et al., 2016). In these enterprises, the federated approach has been considered to provide the best perspective to develop full enterprise interoperability in the future (Tu et al., 2016). Working in a cross-enterprise product realization process means that the flow of information and material needs to be efficiently managed throughout the entire life cycle, i.e. from concept to disposal. Due to the topology of an extended enterprise, the flows of information and materials become complex especially if the configuration of the extended enterprise changes dynamically during collaboration projects. This highlights the use of Manufacturing Execution Systems (MES) and their integration with planning and management systems.

Today an enterprise's competitiveness is to a large extent determined by its ability to seamlessly interoperate with others and the advantage of one enterprise over another stems from the way it manages its process of innovation (European Commission, 2008). The differentiation with the competitors in the manufacturing domain will be increasingly based on additional digital services, and these services will be created by gathering and assembling information coming from value chain partners (Zacharewicz et al., 2017). One of the problems is that partners use different processes, organizations and different Enterprise Information Systems (EIS), which leads to horizontal barriers of interoperability (Zacharewicz et al., 2017). Enterprise Interoperability (EI) has therefore become an important area of research to ensure the competitiveness and growth of European enterprises (European Commission, 2008).

As illustrated in Figure 1, attempts towards the Interoperability Service Utility are bound to drive and utilize developments in Future Internet and Enterprise Systems, while adopting and fertilizing evolutions in the Knowledge and Semantic Interoperability

domain (European Commission, 2008). The Mediation Information System Engineering (MISE) approach aims at defining and designing a platform dedicated to initiate and support any collaborative situation among potential partners (Benaben et al., 2018). A Scientific Base for EI should, in the meantime, act both as a repository of generated knowledge but also as an incubator of new ideas and future challenges to target (European Commission, 2008). Such an objective requires defining an engineering approach, exploiting the adequate collaborative knowledge to design a Management Information Systems (MIS) according to a technical architecture where these three elements (engineering approach, collaborative knowledge and technical architecture) are the main components that should be studied, selected and defined in order to describe the MISE approach (Benaben et al., 2018, 2013).

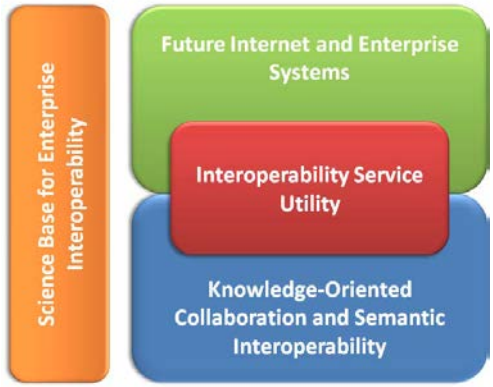

Figure 1. Enterprise interoperability grand challenges and research challenges (European Commission, 2008).

Thesis Background and Research Motivation

Knowledge Management (KM) is one of the key aspects associated with various business processes and job tasks. The focus of this thesis research is on the relationship between knowledge management processes; systems; work efficiency and human behavior. From a technical viewpoint, it is very important to build reliable integration interfaces between various systems involved in the knowledge management workflow. Presumably, the most important factor in the uses and gratifications theory is the system usability and content reliability; thus, testing and implementation of the products or services are playing the main role in the spread of services.

The author has worked for twenty years on various Enterprise Content Management (ECM) and Enterprise Resource Planning (ERP) systems implementation and development projects. Ten years ago, the paradigm was to build all-in-one solutions where some ECM or ERP solution has been chosen as a platform and all enterprise processes were developed on top of it. Today's new paradigm in the age of digital transformation is to implement various smaller and process specific integrated systems which all together aims to create a complete and flexible solution. However, the real life is often somewhat different, where integrations between different systems are not fully reliable and complete, and which is why there is a lot of poorly managed and overlapping content. This situation usually reduces work efficiency and employee motivation in various aspects.

Current thesis studies Knowledge Management Systems (KMS) implementation issues and various influenced aspects of technological, as well uses and gratifications theory viewpoints. The main focus is on work efficiency related to KMS tools where most important technical aspects are integration interfaces between various systems and system usability.

For theoretical novelty the qualitative data for problem statement and quantitative data for the analysis were collected from a large service desk company by KMS focus groups and a web survey which is described in Chapter 2. For practical novelty the prototyped cases address the technological issues which are described in Chapter 3 and Chapter 4.

The results of the research were published in several international conference proceedings and journals. For theoretical science, the most influential publication is Paper IV in the International Journal of Information Management, published in cooperation with a foreign research group where the author participated within one academic semester. The results and findings from qualitative research are valuable for practical implementation in the company where the survey was conducted.

Thesis Objectives and Hypotheses

Current thesis addresses the following main objective:

To increase intra- and inter-organizational processes interoperability and efficiency, by knowledge collaboration and information management systems integration.

To achieve the objective, the following tasks (cases) were planned:

1. analysis of Knowledge Management Systems to conduct focus groups and a survey in Nordic Service Desk Department of a world leading IT services corporation, survey analysis results and conclusions generalized for Small and Medium-sized Enterprises;
2. analysis of different layers of fault tolerance in integration interfaces of Information Systems, prototype development and testing of integration interface for Enterprise Resource Planning solution by using multi-layer architecture;
3. development and implementation of a database solution to achieve collaboration between different services, generalized prototype solution for testing and implementation of products and services to ensure the spread of services.

The working hypotheses (H-zero) can be formulated as:

1. utilization of knowledge management systems is directly influenced by knowledge quality and ease of access, which can be increased by integrating various knowledge sources and improving search functionality;
2. efficiency of knowledge retrieval and contribution processes can be increased through interoperability, considering the uses and gratifications theory together with machine to machine technology opportunities;
3. to ensure successful usage of Information Systems or various products and services, in addition to the system design and architecture issues, the implementation and testing process must be paid high attention.

Abbreviations

API	Application Programming Interface
AVG	Average
AWS	Amazon Web Services
CIO	Chief Information Officer
CRM	Customer Relationship Management
CSB	Cloud Service Broker
CSCL	Computer Supported Collaborative Learning
CV	Control Variable
DSM	Data Stream Mining
DSS	Decision Support Systems
DV	Dependent Variable
EAS	Enterprise Estonia
ECM	Enterprise Content Management
EI	Enterprise Interoperability
EIS	Enterprise Information Systems
EKR	Electronic Knowledge Repository
ERP	Enterprise Resource Planning
ESB	Enterprise Service Bus
ICT	Information and Communication Technology
IMECC	Innovative Manufacturing Engineering Systems Competence Centre
IoE	Internet of Everything
IoT	Internet of Things
IS	Information Systems
IT	Information Technology
IV	Independent Variable
KB	Knowledge Base
KM	Knowledge Management
KMS	Knowledge Management Systems
LTE	Long-Term Evolution
MES	Manufacturing Execution Systems
MIS	Management Information Systems
MISE	Mediation Information System Engineering
MM	Mediator / Moderator
MS	Microsoft
NAS	Navision Application Server
NAV	MS Dynamics NAV (formerly Navision)

OMG	Object Management Group
PaaS	Platform as a Service
PC	Personal Computer
PLM	Product Lifecycle Management
SD	Service Desk
SME	Small and Medium-sized Enterprises
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SOI	Service-Oriented Integration
SOMDP	Service-Oriented Message Driven Platform
STDEV	Standard Deviation
TTÜ	Tallinn University of Technology
UAS	User Administration Services
UGT	Uses and Gratifications Theory
WiFi	Wireless Fidelity
VE	Virtual Enterprise

1 Literature Review

Major corporations, alliances, and large state-owned companies control today's global market, on the other hand, more than 99% of European businesses are **Small and Medium Enterprises** (SME) (Polyantchikov et al., 2017). Therefore, an important research question is the following: Is it possible to create an environment which combines a significant amount of SME resources, and directs them towards effectively fulfilling a common goal (Polyantchikov et al., 2017)? The term **Virtual Enterprise** (VE) signifies a grouping of legally distinct or related enterprises coming together to exploit a particular product or service opportunity and the next phase of Enterprise Interoperability, the sharing of knowledge within a VE to the mutual benefit of the VE partners, this especially includes knowledge about how to create, operate and integrate successful VEs (European Commission, 2008).

The third era of industry came about with the advent of computers and the beginnings of automation, when robots and machines began to replace human workers on those assembly lines, and now we enter **Industry 4.0**, in which computers and automation will come together in an entirely new way (Marr, 2016). Figure 1.1 introduces Industry 4.0, called the "smart factory"; among other aspects, it addresses interoperability where machines, devices, sensors and people connect and communicate with one another (Marr, 2016).

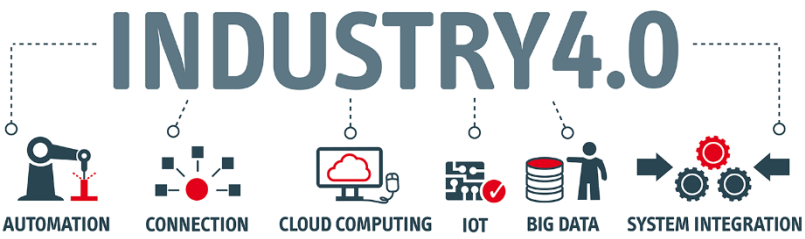

Figure 1.1. Main components of Industry 4.0 (Neosoft, 2018).

Smart devices and cyber-physical systems form the basis for the arising **Internet of Everything** (IoE), which is interconnected to IT systems and opening up new economic opportunities for its participants and users beyond its technological aspects and challenges (Pfisterer et al., 2016). Connected Communities and the related enabling technologies (Personal Smart Devices, multiple communication networks as WiFi, Bluetooth, LTE, Smart Sensors, etc.) set the scene of a new class of emergency and decision support systems based on knowledge, real-time situational awareness, and personalized communication (Bellini et al., 2017). The Internet is expanding beyond Personal Computers (PC) and mobile devices into enterprise assets such as field equipment, and consumer items such as cars and televisions where the combination of data streams and services created by digitizing everything creates four basic usage models – Manage; Monetize; Operate; Extend (Gartner, 2015). These four basic models can be applied to any of the four "internets" (people, things, information and places) and enterprises should not limit themselves to thinking that only the Internet of Things (i.e., assets and machines) has the potential to leverage these four models (Gartner, 2015). The Internet portals have been constantly developed by using new technologies; however, such portals cannot always meet the requirements of the IoE communication between people and things or between things themselves (X. Chen et al., 2017).

One of the biggest technology trends will be the one that remains essentially invisible to the vast majority of people on the planet, even though its eventual impact on humankind will be dramatic (Oracle, 2015). **The Internet of Things** (IoT) will finally become a reality, principally due to the rapidly falling cost of manufacturing power-efficient wireless chipsets capable of sending and receiving WiFi and Bluetooth low-energy signals (Oracle, 2015). Advanced Information Technologies (IT) have facilitated new ways of generating and gathering data rapidly by using Data Stream Mining (DSM), where the IoT plays a significant role, with a typical meaning of a tough and challenging computational case of big data (Lan et al., 2017).

In the IoT, identification and resolution of a physical object is crucial for authenticating object's identity, controlling service access, and establishing trust between the object and cloud service and together with the development of computer vision and pattern recognition technologies, face has been used as a high-security identification and identity authentication method that has been deployed in various applications (Hu et al., 2017). In the process of identification, various physical objects are respectively identified and associated by the corresponding identifiers, so that network and applications can control and manage these objects with an identifier to implement information acquisition, processing, access control, transmission and exchange throughout both physical-space and cyber-space (Hu et al., 2017). Social behavior and appropriate use become even more crucial as we build out the IoT, an increasingly interconnected cyber-physical-biological environment that links devices, systems, data, and people - at its best, the IoT has the potential to create an integrated ecosystem that can respond to a spectrum of needs, increasing efficiency and opportunity, and empowering people through technology, and technology through intelligence - at its worst, the IoT can open a Pandora's Box of inappropriate and unsafe behavior, unintended consequences, and intrusiveness (Berman et al., 2017).

Context-Rich Systems have been a Gartner favorite for a long time and with a good reason because the use of systems that utilize situational and environmental information about people, places and things in order to provide a service, is definitely on the rise and IT needs to look at creating ever more intelligent user interfaces linking lots of different apps and data (Gartner, 2015).

Bringing together personal clouds and external private cloud services is an imperative and enterprises should design private cloud services with a hybrid future in mind and make sure future integration/interoperability is possible because **Hybrid Cloud** services can be composed in many ways, varying from relatively static to very dynamic (Gartner, 2015). Managing this composition will often be the responsibility of something filling the role of **Cloud Service Broker** (CSB), which handles aggregation, integration and customization of services where enterprises that are expanding into hybrid cloud computing from private cloud services are taking on the CSB role (Gartner, 2015). The hybrid cloud idea is increasingly gaining momentum because it brings distinct advantages as a hosting platform for complex software systems, however, several challenges need to be surmounted before hybrid hosting can become pervasive and penetrative (Venkateswaran et al., 2018).

For example, one challenge about hybrid mobile cloud resource provisioning is the trade-offs between energy consumption and how resources, such as processing power and network, are being utilized and where the elastic hybrid mobile cloud resource provisioning model is jointly optimized to improve mobile user experience (Chunlin et al., 2017).

Through 2020, the **Smart Machine** era will blossom with a proliferation of contextually aware, intelligent personal assistants, smart advisors (such as IBM Watson), advanced global industrial systems and public availability of early examples of autonomous vehicles and new systems that begin to fulfill some of the earliest visions for what information technologies might accomplish - doing what we thought only people could do and machines could not - are now finally emerging (Gartner, 2015). Gartner expects individuals will invest in, control and use their smart machines to become more successful and enterprises will similarly invest in smart machines where consumerization versus central control tensions will not abate in the era of smart-machine-driven disruption (Gartner, 2015).

Cognitive smart city refers to the convergence of the emerging IoT and smart city technologies, their generated big data, and artificial intelligence techniques among the commercial products that move toward cognitive frameworks (Mohammadi et al., 2018). IBM Watson offers a cognitive system with several analytics and machine learning services that rely on dynamic learning (i.e., the learning process is improved in future rounds based on the feedback from previous rounds) (Mohammadi et al., 2018). Cognitive computing is a term used by IBM to describe systems that can learn from a wide range of datasets, are able to provide reasons, can interact with humans through natural languages, and gain their experiences in the context (Mohammadi et al., 2018).

Forrester draws a comparison between **Service-Oriented Architecture** (SOA) and **Application Programming Interfaces** (API), like the former, the latter provides open access to useful functionality through network-based services using technologies that are readily accessible from a broad range of programming environments (Forbes Forrester, 2015). The emergence of Open APIs at news organizations represents a shift toward an open innovation paradigm that, in theory, might help address the R&D challenges facing the news industry, as well as the challenges in finding new revenue models through a study of four leading cases of Open API deployment − NPR, The New York Times, The Guardian and USA Today (Aitamurto et al., 2013). The deployment of Open APIs is one of the first steps in applying open innovation principles in digital media and functions as a strategic tool to enhance innovation processes within and beyond organizations' boundaries (Aitamurto et al., 2013). Furthermore, by fostering innovation networks, organizations can reach out to new markets, create extended product portfolios, and meet the needs of increasingly fragmented audiences (Aitamurto et al., 2013).

Big Data, it is varied; it is growing; it is moving fast, and it is very much in need of smart management where data, cloud and engagement are energizing organizations across multiple industries and present an enormous opportunity to make organizations more agile, more efficient and more competitive (IBM, 2015). Thus, in order to capture that opportunity, organizations require a modern Information Management architecture (IBM, 2015). Advances in technology and expanding data collection opportunities (e.g., customer relationship management, social media, and e-retailing) have resulted in a proliferation of new data sets and the formation of big data research (Gillespie et al., 2018). Today's global manufacturing landscape is changing fast. Current technology advancement and big data development allow managers to have better insights into their operations where the IoT and big data provide enormous possibilities for firms to improve their operations performance (Tan et al., 2017). The Industry 4.0 and IoT allow for the creation of smart factories where machines and networks are capable of exchanging and responding to information and autonomously managing the production process (Tan et al., 2017).

In business and at home, **mobility** has transformed how we live, work, and play - who has not headed to a meeting only to realize we are not sure of the exact time and location - we rely on our smartphone to quickly get the answer or when we capture our child's first soccer goal or milestone, we reach for our mobile device, which allows us to share the moment almost instantly (Oracle, 2015). For the past decade, most enterprises took a "ready, fire, aim" approach to deploying mobile technologies and these efforts tended to be tactical, coming in response to rapidly proliferating devices and applications (Oracle, 2015). The pressure to support mobile devices has increased in the last several years and more enterprise stakeholders accessing information while on the move and the initial temptation for Chief Information Officers (CIOs) was to be in control of the mobile device – its connectivity, security, and form factors - addressing all of these features uniformly for all employees (Venkatesh et al., 2014).

1.1 Uses and Gratifications Theory

Uses and Gratifications Theory (UGT) is used to investigate why people use media, as well as the gratifications that are derived from media usage and access (Luo et al., 2014). UGT originates from researches in traditional mass media communication contexts, such as radio and television [Paper IV]. In past decades, UGT has been used to examine the use of new forms of media and applications in the Internet context, such as online websites, social networking services, mobile applications, online games, and virtual communities [Paper IV]. By and large, UGT has always provided a cutting-edge theoretical approach in the initial stages of each new mass communications medium: newspapers, radio, television, and now the Internet (Ruggiero, 2000).

Illustrated in figure 1.2, the UGT suggests that consumers play an active role in selecting and using a particular media (Hasan, 2017; Matei, 2010). According to UGT, consumers actively evaluate the available media and they select the media or innovation that they believe will satisfy their needs and maximize their gratification, UGT states that the audience selects media based on personal needs and knows which media can satisfy their needs (Hasan, 2017; Lin et al., 2017; Patwardhan et al., 2011).

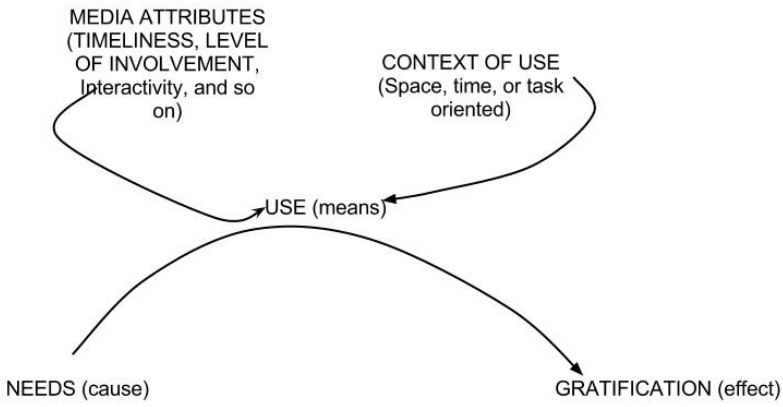

Figure 1.2. Uses and gratifications core concepts (Matei, 2010).

Lichtenstein and Rosenfeld (1983) first proposed that medium-specific gratifications are predicted by characteristics of media themselves rather than innate needs or perceptions of use (Sundar et al., 2013). This essentially means that certain gratifications are predicted by using different types of technologies, rather than felt needs (Sundar et al., 2013). Given this, a distinct possibility is that the affordances of modern media will lead users to expect certain gratifications and thereby shape the fulfillment that they receive by using these media (Sundar et al., 2013).

There have been several studies on the ERP systems based on UGT approach in IS domain where the success rates of ERP implementations have been linked to the extent to which users are willing to accept and use these systems (Hasan, 2017; Hwang et al., 2011). In particular, perceived informativeness of an ERP system had significant positive effects on both attitude and satisfaction with an ERP (Hasan, 2017). This finding reaffirms the value that users place on the information that they fetch from an ERP system and provides additional empirical support for the key role that information plays in ERP acceptance (Hasan, 2017).

UGT provides a strong theoretical foundation for studying IT choice in a consumer context because intrinsic and extrinsic motivations have been well examined in all types of media (Luo et al., 2014).

1.2 Knowledge Management

In the information age, companies increasingly derive value from intellectual rather than physical assets, and employee knowledge is believed to be a company's most profitable resource where Knowledge Management refers to identifying and leveraging the collective knowledge in an organization to help the organization compete (Alavi et al., 2001). Knowledge Management Systems (KMS) are designed to allow companies to manage their knowledge resources and initially, Knowledge Management (KM) approaches focused on knowledge as objects that could be organized to support decision making where KMS were seen as tools to manage codified knowledge, such that most KM projects were initiated top-down and driven by management; however, the rigid structure of such centrally controlled KM initiatives often exhibited poor incentives to the sharing and reuse of knowledge (Arazy et al., 2012).

Over the past decade, researchers and managers have investigated methods for improving organizational performance by providing employees with better ways of accessing one another's knowledge (Durcikova et al., 2009). Such KM efforts often rely on IT, including one important class of KM initiatives that employs IT-based repositories, to capture employees' knowledge and make it available to a broad range of potential internal or external recipients (Durcikova et al., 2009).

Positive content gratifications and technology gratifications are important factors that determine user satisfaction with knowledge (McKerlich et al., 2013). Specifically, information broadcasting rather than social networking is valued by knowledge users, so systems designers should continue to enrich the user interface to facilitate information dissemination (McKerlich et al., 2013). They should also incorporate ubiquity functions into new products and ensure that users can access knowledge from diverse platforms (McKerlich et al., 2013). In the context of personalized advertising applications for smartphones, there are prototyped IT solutions, which retain users' information locally on their smartphones while still providing them with personalized product messages (Sutanto et al., 2013).

As today's organizations seek better methods for managing and reusing their knowledge, the deployment of knowledge repository systems will continue to proliferate, however, the investment in such systems will be fruitful only to the extent that they are utilized by knowledge workers as a means of acquiring and leveraging knowledge from across the organization (Durcikova et al., 2016).

Due to the IT revolution and advancements of the Internet, the value of knowledge assets has been greatly enhanced and many companies are building KMS to manage organizational learning and business know-how (Tseng, 2008). For the modern businesses, Knowledge Management is critical in ensuring process efficiency and improved organizational memory but this does not always lead to higher work efficiency (Ganguly et al., 2011) [Paper IV].

One of the Knowledge Management methods, for example, is to create a website for organizations to function as a tool to relay knowledge to the staff (Ariya et al., 2016). This knowledge has to be able to be relayed through the learning styles that the staff in the organization tends to use when accessing the website or the database, for example, smart phones, tablets, personal computers etc (Ariya et al., 2016). Even though there is a standardized KMS according to the knowledge engineering principles, the main problem is to prove if this system would elevate learning performances of organization staff higher than the former ways of learning–from documents (Ariya et al., 2016).

1.2.1 Implementation of Knowledge Management Systems

It is important for organizations to provide effective leadership during a KMS implementation where business unit leaders play a key role in affecting employees' job performance (Xiaojun, 2017). Employee performance is affected by the extent to which they engage in rich use of a KMS and the performance relationship is dependent on task non routineness, absorptive capacity, and transformational leadership (Xiaojun, 2017).

While a positive effect of KMS use on performance is expected, this impact is likely to be moderated by several contingent factors, depending on the alternative knowledge sources and task environments, the impact of KMS usage may decrease or increase, thus management should not treat two or more IT applications separately but should rather attempt to consider the joint effects of all applications and finally, knowledge workers as users of repository KMS have to clearly understand the potential benefit and cost of reusing codified knowledge (Hyun Kim et al., 2016).

Although many organizations are implementing KMS, there is little empirical evidence about whether KMS use can improve individual performance, and how time and experience influence the value derived from KMS use (Ko et al., 2011). The significance of switching costs is highlighted as a key determinant of user resistance, and it also identifies colleague opinion and self-efficacy for change as antecedents that reduce switching costs; furthermore, the role of the perceived value of IS-related change and organizational support factors are reducing user resistance (Kim et al., 2009).

Attitudinal beliefs, such as task needs, may be a non-critical factor in the formation of positive attitudes towards knowledge seeking; however, system quality, along with compatibility, trust, knowledge growth and knowledge quality, positively affects user attitudes towards knowledge seeking (Lai et al., 2014). To encourage employees in different nations to use deployed global Electronic Knowledge Repository (EKR) more fully, organizations should understand the core mechanism underlying employees' EKR knowledge-seeking behaviors and, more importantly, how this mechanism is jointly affected by national wealth and climate harshness (L. Chen et al., 2015).

To succeed, a repository must contain knowledge that will prove useful for employees looking for answers to their questions and solutions to their problems (Durcikova et al., 2009). That leads to the task of ensuring the quality of knowledge in a repository, which often falls to subject matter experts who filter employees' contributions, rejecting those that are redundant, incorrect, ineffective, outdated, or otherwise unhelpful and without such a validation process, a repository "soon overflows with knowledge assets of questionable value" and can, as a result, lose its credibility with employees (Durcikova et al., 2009).

There are three main issues regarding the use of KMSs: firstly, SMEs adopt and use more intensively traditional tools rather than new and more updated ones that are generally cheaper and easier to use; secondly, SMEs adopt and make more intensive use of practices that do not exclusively focus on the KM process, but seek to adapt practices they already know to the requirements of KM and finally, there is a relationship of reciprocity between KM-Tools and KM-Practices: one reinforces the other and vice versa (Cerchione et al., 2017). When a KMS is perceived to be useful, users tend to reduce the usage of printed documents as a source of knowledge; however, when a KMS is perceived to be useful and easy to use, knowledge sourcing from other individuals is not influenced (Choi et al., 2014).

1.2.2 Knowledge Collaboration and Interoperability

Interoperability is a property referring to the ability of diverse systems and organizations to work together (inter-operate) (Malhotra et al., 2007). To achieve interoperability between different organizations or interest groups, one possible way is to build specific web platforms where structured information can be easily published and consumed [Paper III].

The rapidly increasing competitiveness in the market highlights the importance of design quality, maximizing productivity, multi-company collaboration, optimal price levels and predictability [Paper I]. The main focus of the manufacturer is to innovate, get products to the market faster, reduce errors and increase flexibility [Paper I]. The manufacturers have been continuing to improve their products, information systems developments and management abilities [Paper I]. Because of that, the past years have seen growing investments in the area of Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP), real time monitoring and optimization, and integration technologies of business software and Information Systems (IS) (Zhu et al., 2005) (Cerchione et al., 2017).

The issue of alignment between the nature of an enterprise's knowledge and the KMS used to support the process of KM is extremely important for the following three reasons: (1) an alignment between the nature of the knowledge and the KMSs used is a critical success factor in supporting the different phases of the KM development process (i.e., knowledge creation, storage, transfer/sharing, and application); (2) misalignment between the nature of the knowledge and the KMSs used leads to inefficiency and ineffective use; and (3) over the last twenty years, Information and Communication Technology (ICT) has been offering new opportunities in terms of new, low cost, and easy to use KM tools with a high performance/price ratio (Centobelli et al., 2018). Furthermore, although this topic is crucial to large companies, it is even more important to SMEs, as they usually have few resources to monitor innovation in the KMS sphere (Centobelli et al., 2018).

Many organizations have begun embracing and promoting KMS, but have found that their employees have been overwhelmed by the amount of knowledge thus made available and can be shown that, while the user-rating-based recommendation mechanism was the priority for knowledge seekers, an algorithm-based recommendation mechanism was more influential for knowledge contributors (Sutanto, Jiang, 2013).

1.3 Enterprise Application Integration

The service-centered architecture follows generic model with the focus on the provision of various services identified from the field studies, and is in a spirit similar to that of SOA where service producers and service consumers are not initially designed to fit together, but are matched at run time by the service-oriented middleware (Yang et al., 2012).

Despite the potential benefits, many organizations have failed in SOA implementation projects (Li et al., 2015). To achieve a successful SOA implementation, top management must continue their normative commitment for a duration long enough so that the organization can perceive the benefits that in turn motivate internal organizational commitment to SOA (Li et al., 2015).

Typical "Spaghetti" Enterprise Application Integration where adapters interface with applications at their integration points is presented in Figure 1.3. As shown in the figure, this kind of solution leads to complicated and brittle systems that are prone to failure and require a great deal of IT's time and resources to maintain (Mulesoft, 2018). Moreover, the frequency with which these new systems change has also increased and the speed of these changes cannot be accommodated by traditional point-to-point integration methods (Mulesoft, 2018).

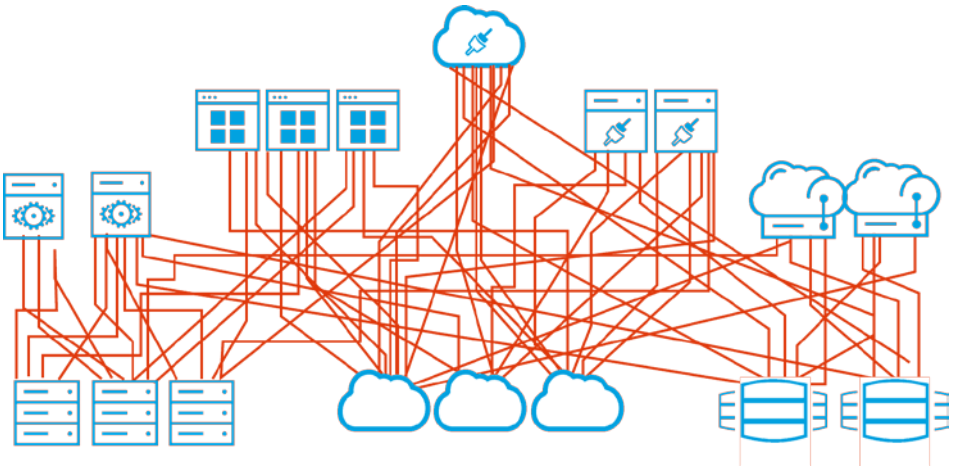

Figure 1.3. "Spaghetti" enterprise application integration (Mulesoft, 2018).

SOA is concerned with the independent construction of services which can be combined into meaningful business processes (Kangilaski et al., 2013) within the context of the enterprise. Adopting a suitable integration strategy requires both an understanding of the business side processes and the IT side technologies where the design of the IT system architecture mainly includes making decisions concerning the IT tools used to support business processes and how various IT solutions and business processes are integrated (Zadeh et al., 2017).

Benefits of the Service Oriented Integration (SOI) Approach are presented in Figure 1.4, where each system is integrated once into the service bus, rather than many times for each point-to-point connection (OMG, 2015). A unified connectivity platform uses the principles behind SOA and the functionality of an Enterprise Service Bus (ESB) to make a truly reusable, service-oriented enterprise architecture that provides the agility and developer ease businesses need to stay competitive in today's environment (Mulesoft, 2018).

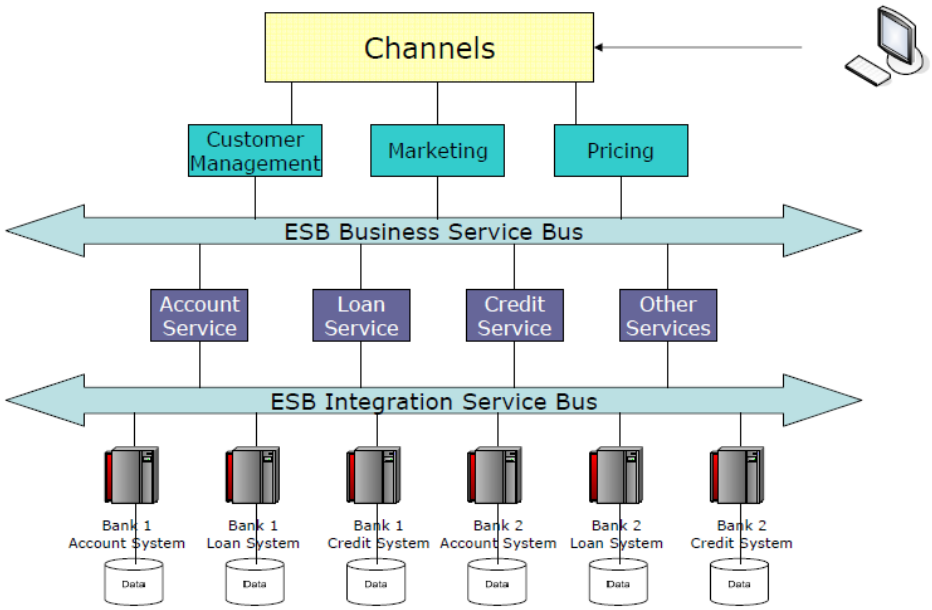

Figure 1.4. SOI enterprise application integration (OMG, 2015).

ESB can be described as providing a set of infrastructure capabilities implemented by middleware technology that enable the integration of services in an SOA (Keen et al., 2004). The true value of the ESB concept, however, is to enable the infrastructure for SOA in a way that reflects the needs of today's enterprise: to provide suitable service levels and manageability, and to operate and integrate in a heterogeneous environment (Keen et al., 2004).

Service Oriented Message Driven Platform (SOMDP) is proposed for constructing a flexible, distributed information integration platform which has not only a good software architecture but can also improve system interoperability, agility and integration capabilities (Bo et al., 2009). As well, it can increase the throughput of the large data processing capability of integration services, while changes in the external load lead to successful adaptability (Bo et al., 2009).

1.4 Intelligent Process Monitoring

Industrial systems are becoming more complex due to the integration of new technologies and materials. At the same time, to satisfy the new developments and implementation time, it makes maintenance and monitoring activities more expensive and complicated. This situation motivates the researchers to look for innovative ways of production monitoring (Snatkin et al., 2015).

Production process monitoring can be divided into three main groups - Product tracking, Process parameters, and Process efficiency (Eiskop et al., 2014; González-Galván et al., 2008). Process monitoring is a very valuable input for Decision Support Systems (DSS) and together with KMS can build a full solution for decision making and future prediction.

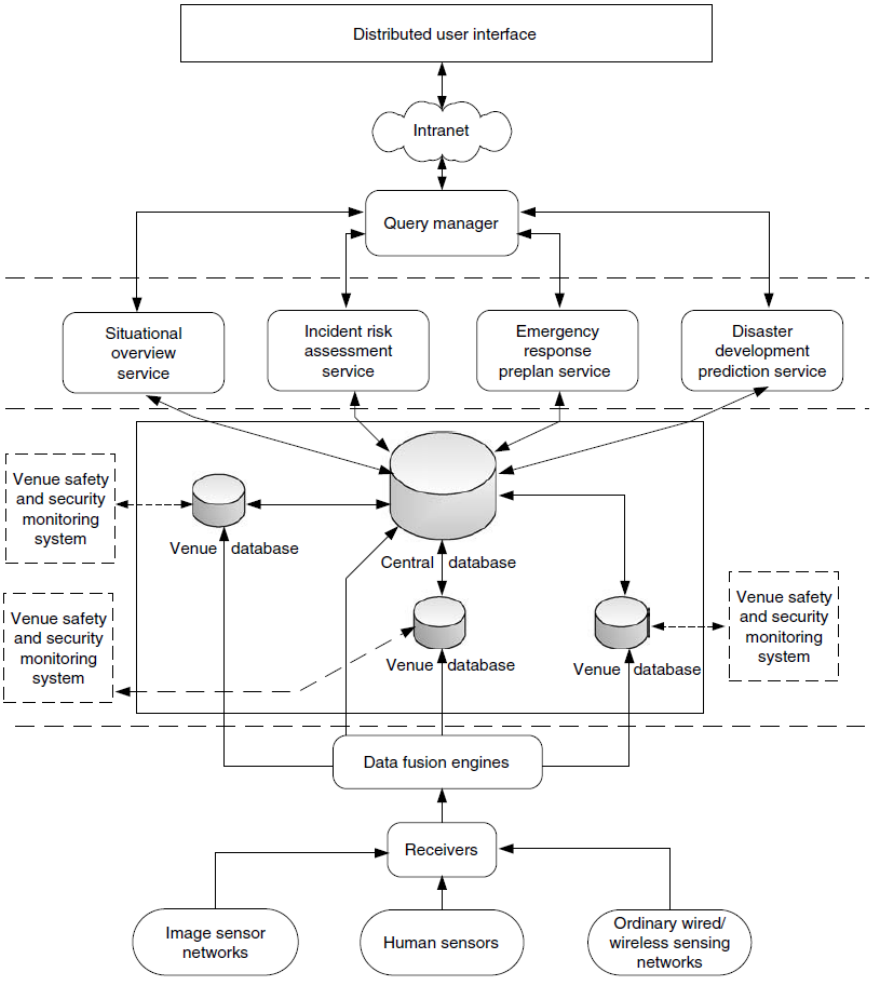

Figure 1.5. Data collection and decision making system (Yang et al., 2012).

The phrase DSS is an umbrella term used to describe computer applications that enhance the user's ability to make decisions, more specifically, the term usually refers to IS, which facilitates decision-making activities (Yang et al., 2012). Shown in Figure 1.5, it could be an automatic decision-making system such as an autonomic aviation system, but in most cases, it refers to a support system that helps decision makers use communications technologies, data, documents, knowledge, and/or models to identify and solve problems, complete decision process tasks, and present recommendations (Yang et al., 2012).

2 System Analysis

As the first case of the thesis, this chapter addresses analysis of enterprise information management systems for interoperability. The following describes a Knowledge Management Systems improvement project in cooperation between Tallinn University of Technology (TTÜ) and Nordic Service Desk (SD) Department of a world leading IT services corporation. Nordic SD Department is using KMS in daily activities, providing customer support for various international customers where SD activities are managed and coordinated by Finnish head office; however, several 1st Level support activities are provided by subsidiaries in Estonia and Poland [Paper I].

Collaboration was made with the SD Department of a large technology provider where the SD Department under study provided support for customers' technical problems [Paper IV]. It is common for the SD Department to cover countless technology-related products and services, such as software, hardware, or network-related issues [Paper IV]. Given that the complexity of IT infrastructures has significantly increased in the last years, customers may encounter a wider range of technical problems that require increasingly complex solutions and consequently, customers may often need to wait considerably longer or even contact SD specialists several times before their enquiries are adequately addressed [Paper IV].

The SD Department under study faces two important challenges in responding to customers' enquiries [Paper IV]. First, the SD Department is the customer's first contact point for support and customers expect instant answers to their questions from its employees [Paper IV]. Second, an important goal for the SD Department is to reduce call-handling duration via continuous tracking and efficiency assessment, and it is required to develop mechanisms that enable SD specialists to solve the overwhelming customer enquiries [Paper IV].

2.1 Knowledge Management Systems Survey

The organization created and implemented two KMSs, namely Infoweb and KB where both of these KMSs are deeply embedded in the SD Department's daily work [Paper IV]. When responding to customer enquiries, the SD specialists will normally attempt to find the answers to the enquiries using Infoweb [Paper I]. If, regarding actionable knowledge, answers cannot to be found in the Infoweb, the SD specialists can alternatively gain in-depth knowledge with the help of KB [Paper IV]. Although these two systems were designed to complement each other in the SD practice, it appears that the SD specialists have repeatedly encountered difficulties in applying relevant knowledge from these two systems [Paper IV]. In this sense, a significant proportion of customer specialists have been employing custom methods to help them compensate for the shortcomings of these KMSs and they have created and maintained their localized KMS, such as a OneNote file or sorted folders of Word-document files, on their hard drives and use self-created Java-based search tools to search for the knowledge [Paper IV].

The main focus is on the description of theoretical research work for the project to compose a preliminary research model and to publish the survey [Paper IV]. Two rounds of data were collected (i.e., a survey and interviews/focus groups) and findings from the interviews/focus groups are also triangulated to add richness to the survey's findings [Paper IV].

The first milestone was to describe the current KMS situation and collect qualitative and quantitative information by the following:

- draw representative focus groups from KMS end-users;
- conduct per focus group on-site interview;
- prepare a survey to be distributed to all SD 1st Level employees [Paper I].

Focus groups were composed on the basis of different SD team work specifics and locations to represent a cross-section from the SD Department:

- 1st Level SD employees in Estonia, 3-5 focus groups, eight people each;
- 24/7 SD employees in Finland, two focus groups, four people each;
- 2nd Level SD employees in Finland, one focus group, four people [Paper I].

The second milestone was to analyze the uses and gratifications of the current three different KMS solutions:

- analyze the data collected during focus group interviews and filled survey questionnaires;
- summarize conclusions from business viewpoint [Paper I].

Based on the focus group interviews, the following aspects were found to address the survey questionnaire for detailed analysis:

- Knowledge Type;
- Source/Channel of Knowledge;
- Knowledge Quality;
- Knowledge Sharing;
- Routine / Solution Reuse;
- Communication Space;
- Stress Level;
- System Use;
- IT Alignment;
- Productivity;
- Customer Satisfaction [Paper I].

2.1.1 Constructs and Preliminary Research Model

Constructs are based on and composed according to the research publications mainly from the last ten years on the KMS field. According to the keyword search, close to 100 papers were investigated, including 15 directly used as references for the constructs [Paper I].

The main research model variables for the survey are: knowledge search simplicity; quality of the retrieved knowledge; the extent of knowledge retrieval; and work efficiency, regarding the control variables, the factors considered were previously shown in the literature to affect knowledge retrieval and work efficiency [Paper IV].

Survey constructs were grouped to the categories and each construct was classified with the preliminary type of: Independent Variable (IV); Mediator / Moderator (MM); Dependent Variable (DV); Control Variable (CV). Constructs have literature references from preceding research studies.

Research model contains 28 constructs in total, which are combined as a preliminary model and investigated by the survey. The first list presents construct counts by variable type, followed by a full list of constructs grouped into the following categories:

- Control Variables (CV) – 9 constructs;
- Independent Variables (IV) – 8 constructs;
- Mediator / Moderator (MM) – 4 constructs;
- Dependent Variables (DV) – 7 constructs.

Category 1 – Background:

1. Current Location / CV;
2. Current Team / CV;
3. Current Position / CV;
4. Experience in Current Position / CV;
5. Experience in Area of Work / CV;
6. Age / CV;
7. Gender / CV;
8. Work Expertise / CV (Durcikova et al., 2009).

Category 2 – Environment:

1. Training / CV (C.-J. Chen et al., 2009);
2. Job Stress Level / IV (Shigemi et al., 2000);
3. Time Pressure / IV (Gray et al., 2006);
4. Case Analyzability / IV (Adler, 1995; Nidumolu, 1995);
5. Case Variability / IV (Gelderman, 2002; Zimmer et al., 2008);
6. Satisfaction with Quality of Knowledge / MM (Durcikova et al., 2009).

Category 3 – Process:

1. Sourcing from Colleagues / DV (Gray et al., 2006);
2. Sourcing from Local Documents / DV (Gray et al., 2006);
3. Knowledge Contribution / DV (Koh et al., 2003; Meng et al., 2007; Wasko et al., 2005);
4. Simplicity of Information Update Functionality / IV;
5. Information Update Autonomy / IV (Durcikova et al., 2009).

Category 4 – Systems:

1. Frequency of Accessing Channel of Knowledge / MM (Durcikova et al., 2009);
2. Simplicity of Search Functionality / IV;
3. Search Results Presentation / IV;
4. Sourcing From Repository / DV (Gray et al., 2006);
5. Time Efficiency of Retrieving Knowledge / MM (Bstieler et al., 2010; Cooper et al., 1994);
6. Time Efficiency of Storing Knowledge / MM (Bstieler et al., 2010; Cooper et al., 1994).

Category 5 – Outcomes:

1. Operation Efficiency / DV (Henderson et al., 1992);
2. Operation Performance / DV (Henderson et al., 1992);
3. Customer Satisfaction Target / DV.

The conceptual validation was carried out using structured sorting (with variable category labels) where the goal was to gain a clear indication that the survey items are indeed measuring what they are supposed to measure [Paper IV]. A set of five judges (researchers with substantial experience in the fields of information systems and knowledge management) were asked to sort the items and based on the sorting results, the scales were revised and another round of sorting was conducted to confirm the construct validity [Paper IV]. Following this positive result, the survey was distributed to the SD specialists [Paper IV].

2.1.2 Survey Publishing

According to the methods for scales composing, it was decided to use six-point Likert scales from strongly disagree to strongly agree (never to very frequently for the knowledge retrieval variable) [Paper IV].

Each construct was measured by 2-3 consistent survey items and all the survey items were validated by using a sorting method to prove that they firmly represent associated constructs [Paper I].

A Web-based survey was published only in the English language to 400 employees at SD 1st Level and the questionnaire was fully completed by 158 employees [Paper I]. Survey results of the current project phase together with the preliminary research model based on constructs will be input for the next project phase where the statistical analysis was done [Paper I]. According to the results from the statistical analysis in the final project phase, the research model was validated, and project conclusions were drawn [Paper I].

To gain a better understanding of knowledge workers' (perception-based) gratifications toward the organization-created KMS, interviews and focus groups with a total of 45 SD specialists were conducted [Paper IV]. During the interviews, questions were specifically asked about the functionalities and the usage behavior of the KMS [Paper IV]. A comprehensive understanding of knowledge retrieval practices in the SD Department was obtained from the interviews, which adds richness to the findings [Paper IV].

2.1.3 Survey Results

The customer support specialists have clear time targets that need to be achieved, and they need to efficiently address questions from customers [Paper IV]. On a daily basis, they receive up-to date summaries of their efficiency of the previous day and the whole week [Paper IV]. Thus, their responses were cross-checked with summaries of their work efficiency to ensure that the self-reported work efficiency reflected their actual work efficiency [Paper IV].

Fully completed questionnaires showing distribution of participants in age, gender, position, experience, team and country are presented in Tables 2.1, 2.2 and 2.3. All the values are counts from a total of 158 questionnaires.

Table 2.1. Age and gender distribution

Age / Gender	Female	Male	Total
21 and Under	0	2	**2**
22 to 34	27	73	**100**
35 to 44	17	21	**38**
45 to 54	9	4	**13**
55 to 64	3	2	**5**
65 and Over	0	0	**0**
Total	**56**	**102**	**158**

Table 2.2. Position and experience distribution

Position / Experience	Less than 6 months	6 months to 1 year	1 to 2 years	2 to 5 years	5 to 10 years	More than 10 years	Total
User Administration Specialist	0	1	1	7	4	1	**14**
Customer Support Specialist	9	25	18	28	25	7	**112**
Customer Coordinator	4	6	7	8	2	0	**27**
Incident Coordinator	1	0	1	0	1	0	**3**
Group Coordinator	1	0	0	0	0	0	**1**
Group Manager	0	0	0	1	0	0	**1**
Total	**15**	**32**	**27**	**44**	**32**	**8**	**158**

Table 2.3. Team and country distribution

Team / Country	Estonia	Finland	Poland	Total
Regular Working Hours Service Desk (SD)	36	89	0	**125**
Round the Clock Service Desk (SD 24/7)	0	8	0	**8**
Retail Customers Service Desk (Retail)	9	0	0	**9**
User Administration Services (UAS)	10	3	0	**13**
Regular Working Hours Service Desk (GDC SD)	0	0	3	**3**
Total	**55**	**100**	**3**	**158**

Tables 2.4 and 2.5 below present statistical average (Avg.) and standard deviation (STDEV) values for all constructs with Consent and Extent scale types. Colors in average value columns are on the color scale from red to green in correlation with values from one to six. Table 2.4 contains constructs related to general processes.

Table 2.4. Constructs measured without sub-constructs

Construct	Avg.	STDEV
C1-8 Work Expertise	4,9	0,9
C2-1 Training	3,9	0,9
C2-2 Job Stress Level	4,2	0,8
C2-3 Time Pressure	4,0	1,1
C2-4 Case Analyzability	4,4	0,8
C2-5 Case Variability	4,4	1,0
C3-1 Sourcing from Colleagues	5,0	0,8
C3-2 Sourcing from Local Documents	4,3	1,1
C5-1 Operation Efficiency	4,8	0,8

Table 2.5 contains constructs directly related to information systems, clarified in the questionnaire by using three sub-constructs. Total column is calculated as an average from the sub-constructs:

- Infoweb - existing and longtime used KMS application;
- KB - newly implemented KMS application;
- Local - various local repository solutions.

Table 2.5. Constructs measured with sub-constructs

	Average / Standard deviation							
Construct	**Infoweb**		**KB**		**Local**		**Total**	
C2-6 Satisfaction with Quality of Knowledge	3,9	1,3	3,0	1,3	3,9	1,2	**3,6**	**0,9**
C3-3 Knowledge Contribution	3,9	1,5	2,1	1,1	3,7	1,5	**3,2**	**0,9**
C3-4 Simplicity of Information Update Functionality	4,4	1,4	2,5	1,3	4,3	1,4	**3,7**	**0,9**
C3-5 Information Update Autonomy	4,1	1,1	3,4	1,0	4,0	1,1	**3,8**	**0,8**
C4-1 Frequency of Accessing Channel of Knowledge	4,7	1,5	2,1	1,3	4,2	1,4	**3,7**	**0,9**
C4-2 Simplicity of Search Functionality	4,2	1,5	2,5	1,3	4,3	1,4	**3,7**	**0,9**
C4-3 Search Results Presentation	4,0	1,4	2,8	1,3	4,0	1,4	**3,6**	**1,0**
C4-4 Sourcing from Repository	4,4	1,4	2,3	1,2	4,1	1,3	**3,6**	**0,8**
C4-5 Time Efficiency of Retrieving Knowledge	4,1	1,3	2,8	1,3	4,1	1,3	**3,7**	**0,9**
C4-6 Time Efficiency of Storing Knowledge	4,2	1,3	2,7	1,2	4,2	1,2	**3,7**	**0,8**

Based on the descriptive statistics of the survey items, it seems that the respondents' perceived knowledge quality and search simplicity of KB (organization-created system and populated content) are much lower compared to the Infoweb (organization-created system, SD specialists-created content) and Local KMS (SD specialists-created system and content) [Paper IV]. Moreover, it seems that they retrieved knowledge more frequently from the Infoweb and Local KMS [Paper IV].

Correlation analysis results are illustrated in the following research model (Figure 2.1), where connections are drawn for correlation coefficients higher than 0,5.

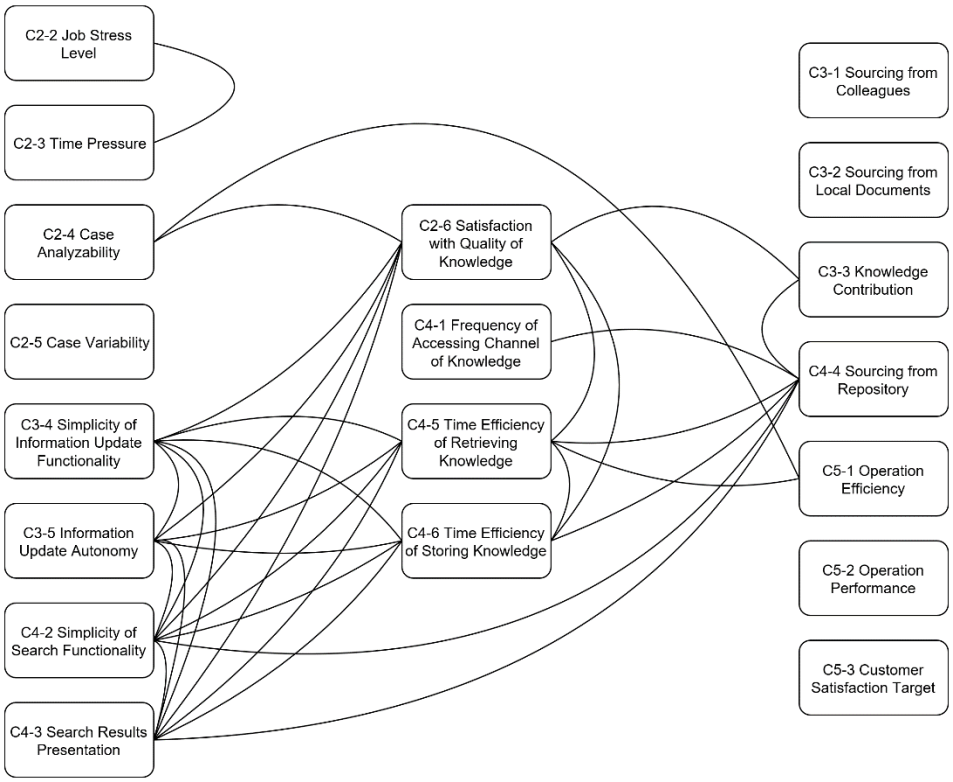

Figure 2.1. Construct correlations.

Based on the overlapping correlations, constructs were grouped and constructs without any correlations were removed from the model. The following new constructs were composed and presented with reference to the original constructs.

Independent Variables (IV)

1. Time Pressure
    a. C2-3 Time Pressure
2. Case Analyzability
    a. C2-4 Case Analyzability
3. Information System Functionality
    a. C3-4 Simplicity of Information Update Functionality
    b. C3-5 Information Update Autonomy
    c. C4-2 Simplicity of Search Functionality
    d. C4-3 Search Results Presentation
4. Frequency of Accessing Channel of Knowledge
    a. C4-1 Frequency of Accessing Channel of Knowledge

Mediator / Moderator (MM)

1. Satisfaction with Quality of Knowledge
    a. C2-6 Satisfaction with Quality of Knowledge
2. Time Efficiency of Retrieving and Storing Knowledge
    a. C4-5 Time Efficiency of Retrieving Knowledge
    b. C4-6 Time Efficiency of Storing Knowledge

Dependent Variables (DV)

1. Job Stress Level
    a. C2-2 Job Stress Level
2. Knowledge Contribution
    a. C3-3 Knowledge Contribution
3. Sourcing from Repository
    a. C4-4 Sourcing from Repository
4. Operation Efficiency
    a. C5-1 Operation Efficiency

Table 2.6 presents correlation analysis results for the composed constructs. The final research model is illustrated in Figure 2.2 where connections are drawn for correlation coefficients higher than 0,5.

Table 2.6. Composed constructs correlations

	IV1 Time pressure	*IV2 Case analyzability*	*IV3 Information system functionality*	*IV4 Frequency of accessing channel of knowledge*	*MM1 Satisfaction with quality of knowledge*	*MM2 Time efficiency of retrieving and storing kn.*	*DV1 Job stress level*	*DV2 Knowledge contribution*	*DV3 Sourcing from repository*	*DV4 Operation efficiency*
IV1 Time pressure	1,00									
IV2 Case analyzability	-0,03	1,00								
IV3 Information system functionality	-0,22	0,40	1,00							
IV4 Frequency of accessing channel of knowledge	-0,10	0,15	0,43	1,00						
MM1 Satisfaction with quality of knowledge	-0,16	0,56	0,65	0,32	1,00					
MM2 Time efficiency of retrieving and storing kn.	-0,17	0,48	0,84	0,40	0,68	1,00				
DV1 Job stress level	0,55	-0,19	-0,32	-0,11	-0,22	-0,27	1,00			
DV2 Knowledge contribution	-0,07	0,28	0,50	0,49	0,51	0,47	-0,07	1,00		
DV3 Sourcing from repository	-0,17	0,26	0,62	0,68	0,45	0,59	-0,27	0,57	1,00	
DV4 Operation efficiency	-0,11	0,55	0,46	0,11	0,41	0,51	-0,20	0,23	0,28	1,00

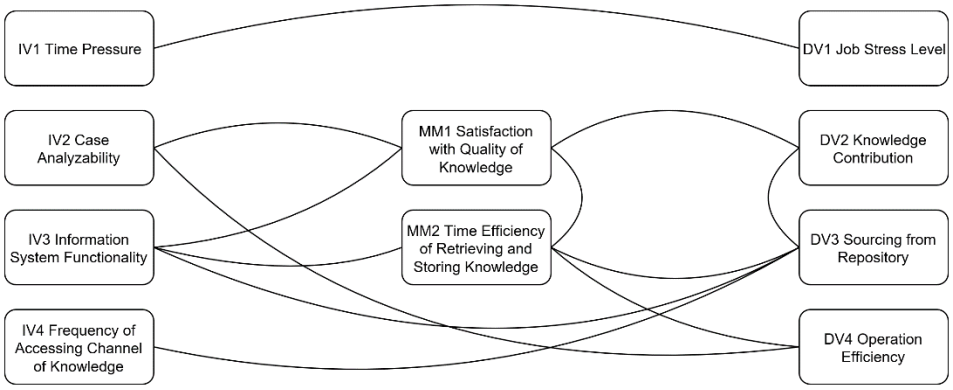

Figure 2.2. Composed research model.

The research model composed illustrates essential constructs with significant correlations where the findings can be summarized as follows:

1. nine control variables (location, experience, age, etc.) do not affect main constructs;
2. time pressure directly causes job stress but has no relation to system usage and operation efficiency;
3. operation efficiency is directly influenced by case analyzability and through time efficiency by information system functionality;
4. knowledge repository utility is directly influenced by the need to retrieve knowledge and by information system functionality;
5. knowledge contribution is related to knowledge repository utility and is influenced through satisfaction with knowledge quality by case analyzability and information system functionality.

2.2 Conclusion

The aim of this study was to examine knowledge worker's retrieval behavior in three types of KMSs and to find out whether frequent knowledge retrieval from these different types of KMSs leads to higher work efficiency [Paper IV]. The investigated call-center company has a unique setting, the employees' work of which is time critical and their work efficiency closely depends on the way they source the knowledge needed to answer customers' questions [Paper IV].

As was shown, the main independent variable is information system functionality, which directly affects the usability of knowledge repository. However, an interesting finding is that operation efficiency is not so directly influenced by information system functionality; thus, we can conclude that results-oriented employees can find different ways and use common sense to achieve their targets.

Although surveys and interviews allowed to obtain an in-depth understanding of the effects of multiple KMSs on SD specialists' work efficiency, their responses were cross-checked against objective reports when visiting customer onsite [Paper IV]. These objective data could not have exported for analytic purposes due to confidentiality issues [Paper IV]. Hence, findings of this study should be viewed in light of the limitation of the study; nevertheless, this study offers several contributions to research and practice [Paper IV].

The main recommendation for companies whose employees' daily work is directly related to knowledge sourcing and contributing is to integrate multiple KMS sources. In principle, it is unnecessary to avoid using multiple KMS sources but it is essential to build integration interfaces and a central search engine that can be easily used to find required information from appropriate KMS database.

Hypothesis 1: "Utilization of knowledge management systems is directly influenced by knowledge quality and ease of access, which can be increased by integrating various knowledge sources and improving search functionality."

Anchoring on the uses and gratifications theory, knowledge workers' knowledge retrieval behavior was investigated and its subsequent impact on their work efficiency under three different KMSs, which differ in the functionality and their related contents [Paper IV]. The KMS survey results show clearly that like in a personal media consumption, as well an organization employees' media consumption is driven by UGT where consumers play an active role in selecting and using a media source.

When organization provided systems did not meet their needs, employees created and maintained their localized KMS, such as a OneNote file or sorted folders of Word-document files and use self-created Java-based search tools to search for the knowledge [Paper IV]. This shows importance of the search engines and reliable integrations between different data sources.

3 System Development

As the second case of the thesis, this chapter addresses development of enterprise information management systems for interoperability. The following describes integration interfaces of business software to analyze fault tolerance and reliability of those interfaces. Main focus of the prototype is on the ERP software Microsoft (MS) Dynamics NAV (NAV), which can be integrated with other business applications as a central business data source [Paper II]. To highlight real-life situations, the sample integration project is used as a case-study, where different fault tolerance levels are used for integration interfaces [Paper II].

Error handling for integration interfaces is very important to build reliable and fault tolerant solutions [Paper II]. Compared to application user interfaces, where a human can react for error situations creatively, the integration interfaces without error handling will just stop working or continue working at inconsistent or looping state, which can cause many problems, in the worst case, also data damages or massive data avalanche or spamming can occur [Paper II].

It is very critical to distribute error handling into described levels adequately and reasonably, so it is important to avoid service level errors in any case [Paper II]. To make decisions between the process and the transaction levels, it is important to calculate optimal cost efficiency because the transaction level is the costliest; however, the process level is sometimes too broad [Paper II].

The case study in this section analyzes NAV implementation of the ERP solution in the organization where there are many internal and external integration interfaces with other applications and IT systems [Paper II]. It is a highly customized solution developed for Enterprise Estonia (EAS) to cover all the main business processes in the organization [Paper II].

External integration interfaces are shown in Figure 2.3, and three internal components of the IT system that are deeply integrated with each other are shown in Figure 2.4.

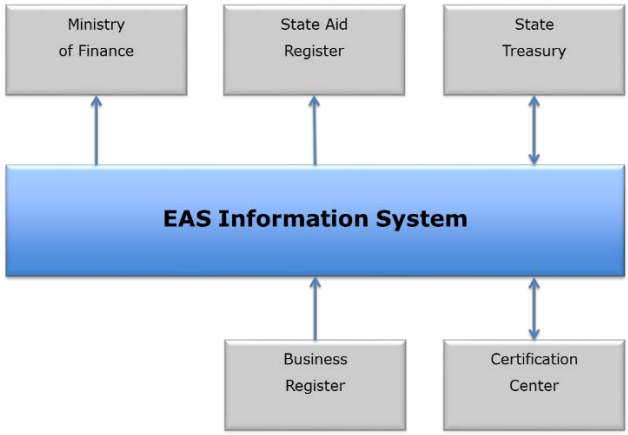

Figure 2.3. External integration [Paper II].

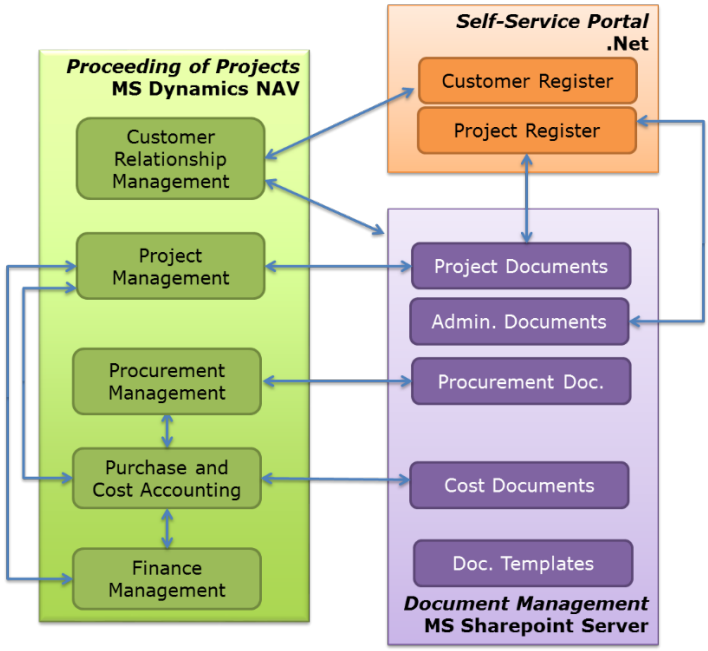

Figure 2.4. Internal integration [Paper II].

3.1 Fault Tolerance in Integration Interfaces

Availability and data consistency in an application shown in Figure 2.5 is traditionally provided through fault tolerant hardware and operating system used by the application for its execution (Huang et al., 1995). New trends are emerging in the marketplace that are changing this tradition; standard commercial hardware and operating systems are becoming highly reliable, distributed and inexpensive to the extent that they are now off-the-shelf commodity items, new application software systems are increasingly networked and distributed, i.e. mostly client-server systems (Huang et al., 1995).

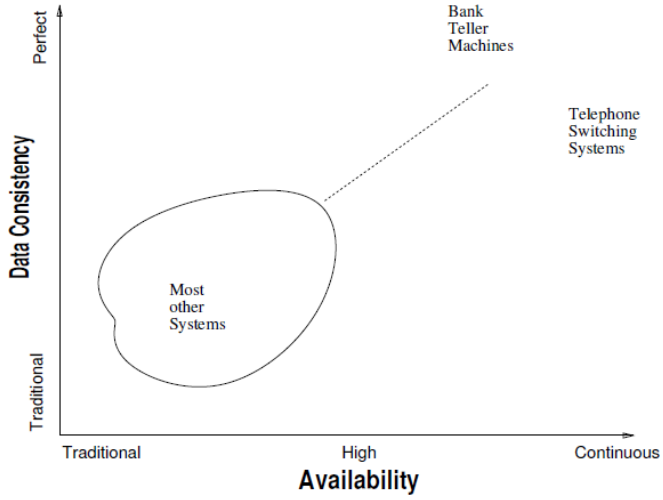

Figure 2.5. Dimensions of fault tolerance (Huang et al., 1995).

Application level fault tolerance for integration interfaces contains different layers to monitor services and handle exceptions [Paper II]. Automated integration interfaces for ERP software NAV are mainly based on the Navision Application Server (NAS) windows service, which operates a number of server-side background processes [Paper II]. To ensure the reliability of those processes, the following is required:

- monitor that NAS service is running by using Windows standard monitoring software;
- monitor that NAS service is alive by communicating one specially designed interface;
- a global framework for processes to handle unexpected errors to keep processes alive;
- per process error handling in database transaction level for continuous processing;
- per transaction error handling to process through all known exceptions;
- watchdog process to send out notifications about exceptions and error situations;
- provide application user interface to access processing and error logs;
- provide a mechanism to make required corrections and initiate recurrent processing [Paper II].

Exception handling level is the best level for reliable error handling to avoid errors handled at the infrastructure level, and because this level is highly application business logic specific, it can react more adequately for errors than infrastructure level [Paper II]. On the other hand, it is also costlier to build very deep error handling at this level because each upper layer at this level can be less unified and will be more business logic specific [Paper II]. User Interface layer is the highest application layer that can be used for basic data validation to avoid processing of invalid data input and to output instant warnings or error messages for user [Paper II].

3.1.1 Service-level Monitoring

This level is used to keep middle tier services running and alive in any unexpected error situation and the system should not cause any errors at this level, so all the errors that occurred at this level need to be analyzed case by case to avoid them in the future:

- monitor that NAS services are running by using Windows standard monitoring software, service states and error messages are logged to Windows Event Log;
- monitor that NAS services are alive through the specially designed interface, service states and error messages are logged to Windows Event Log;
- monitor Windows Event Log messages by using Windows standard monitoring software, according to specified message type and importance initiate specified notifications or actions;
- if service has stopped, then try to restart it; if automatic restart fails, then send out a system critical state notification to administrators;
- send out non-critical notifications about an error and warning situations to maintenance team;
- if an error at this level occurred during the integration process, e.g. during Simple Object Access Protocol (SOAP) request, then the process terminates and integration interface cannot send out any response, i.e. other systems need to wait until timeout occurs [Paper II].

3.1.2 Process-level Error Handling

This level is used to catch known but rare errors that do not need to be handled according to the business logic [Paper II]. This level has unified design by using try/catch methods to enclose all processes, and if an error occurs, then service is skipping the erroneous process and will continue with next processes [Paper II]. In the situation where an erroneous process was preceded for some next process, the next process will probably get the transaction level error [Paper II]. Errors occurring at this level are commonly associated with invalid web service request or invalid input data, so responses sent out at this level are mainly general error messages, e.g. SOAP protocol errors:

- main part at this level is a global and unified framework for processes to handle errors to keep services running and alive;
- error handling is process-oriented with the purpose not to affect other processes if multiple processes are connected at the business logic level, then those relations are not identified;
- the main purpose at this level is to skip erroneous processes and continue with next processes and to avoid infinite loops of the erroneous process;
- global error logging into application level error logs to analyze errors and if necessary, then manually initiate recurrent processing;
- send out notifications according to message types and importance settings;
- if an error at this level occurred during the integration process, e.g. during SOAP request, then unhandled exception response will be sent out [Paper II].

3.1.3 Transaction-level Exception Handling

Exception handling at this level is most advanced and costly, but also most important to keep the system running smoothly and reliably [Paper II]. This level contains exception handling rules at the business logic layer by using if/then methods [Paper II]. Thus, all known possible exception situations are handled by using alternative workflows, which means that exceptions are not just skipped but some alternative way on the workflow can be used to continue positive processing of the transaction [Paper II]. All known and possible error situations can also initiate some alternative workflow or cancel the transaction with predefined error codes [Paper II]. Errors and exceptions at this level commonly are associated with data quality and data validation rules according to associated business logic [Paper II]. Responses sent out at this level are predefined and detail error messages which can be associated as well with the other systems business logic and workflows to define how to proceed most adequately in the situation where an error occurred at this level:

- error handling is transaction-oriented to process through all known exception situations without affecting other transactions in the same process;
- this level is based on business rules and alternative workflows defined for all possible known error and exception cases;
- transaction specific issue logging into application level error logs to analyze cases and if necessary, then makes data corrections and initiates recurrent processing;
- send out notifications according to message types and importance settings;
- if an error at this level occurred during the integration process, e.g. during SOAP request, then response with predefined error/status code will be sent out to the integration interface [Paper II].

3.1.4 User-level Intervention

This level is used for corrective and preventive actions to maintain the system and initiate system improvement tasks to avoid recurring cases hereafter:

- provide user level mechanisms to react for notifications;
- provide an application level user interface to access all processing and error logs;
- provide mechanism to make necessary data corrections and initiate recurrent processing;
- if process level error handling fails for some reason, then terminate abnormal or looping processes;
- analyze occurred issues continuously and initiate system improvement tasks [Paper II].

3.2 Conclusion

Error handling for integration interfaces is very important to build reliable and fault tolerant solutions [Paper II]. Compared to application user interfaces where a human can react for error situations creatively, the integration interfaces without error handling will just stop working or continue working at inconsistent or looping state, which can cause numerous problems [Paper II]. In the worst case, data damages or massive data avalanche or spamming can also occur [Paper II].

Hypothesis 2: "Efficiency of knowledge retrieval and contribution processes can be increased through interoperability, considering the uses and gratifications theory together with machine to machine technology opportunities."

Ten years ago, the paradigm was to build all-in-one solutions where some ECM or ERP solution has been chosen as a platform and all enterprise processes were developed on top of it. Today's new paradigm in the age of digital transformation is to implement various smaller and process specific integrated systems which all together aims to create a complete and flexible solution.

The hypothesis is strongly related to various integrations between different information management systems, thus the reliability of those integrations is essential to achieve a value of a complete solution. Otherwise, based on UGT, enterprise media consumers will find another way to perform their daily work which will meet their local needs in better way. However, such local workaround solutions do not support the global interoperability objectives of an organization.

4 System Implementation

As the third case of the thesis, this chapter addresses implementation of enterprise information management systems for interoperability. Presumably, the most important factor in the uses and gratifications theory is systems usability and content reliability, thus testing and implementation of products or services are playing the main role in the spread of any kind of services. From a generalized viewpoint, there is no difference what kind of products, services or tools will be implemented, i.e. KMS.

Many studies have focused on the usability of groupware in supporting collaborative work (Tang et al., 2014). Unfortunately, our understanding of their impact on collaborative learning is still limited due to a lack of attention on this issue (Tang et al., 2014). Fortunately, Computer Supported Collaborative Learning (CSCL) has benefited from many active studies attempting to understand and provide technological support for learners to cooperate with each other, coordinate their behaviors, and learn collaboratively (Tang et al., 2014). Overall, it can be seen that the addition of collaborative functionality for search tasks can lead to a number of favorable and highly desirable outcomes for end users (Halvey et al., 2010). Search tools have helped the users to complete their search tasks quickly and efficiently, without affecting their search process in a negative fashion, also in terms of task performance, users retrieve more search results in less time with fewer search interactions (Halvey et al., 2010).

This section describes the solution where traineeship mediation process was organized through the Personnel Involvement Platform in TTÜ Department of Mechanical and Industrial Engineering where various Interest groups are associated: students; companies; lecturers and administrators [Paper III].

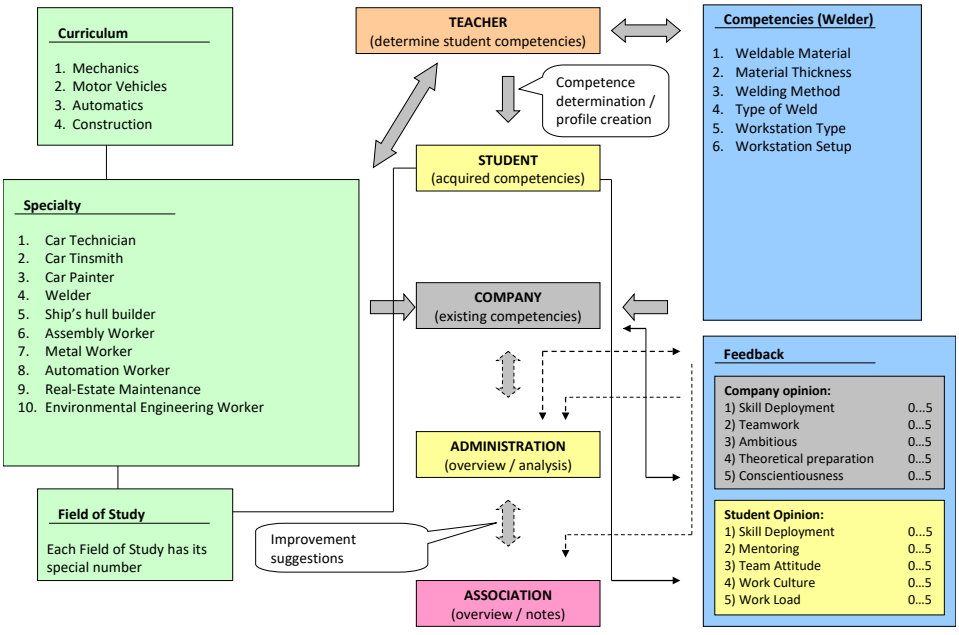

Figure 2.6. Traineeship recruitment process [Paper III].

The traineeship recruitment process presented in Figure 2.6 compared to the regular employee recruitment process contains some specific tasks related to the assignments where university side administrator or lecturer is involved to coordinate the recruitment process and to provide approvals [Paper III].

To meet the needs of those interest groups, the development project was launched to specify all traineeship processes in TTÜ Department of Mechanical and Industrial Engineering and according to those processes, build a specific web platform. During this project, focus is on the following aspects: analysis – how to find out all requirements; design – how to structure requirements from IT solution viewpoint; develop – how to find proper technical architecture; implement – how to go live and involve all interest groups to use the solution [Paper III].

Compared to the current Customer Relationship Management (CRM) and Web platform solutions on the market, the requirements were more specific, so the best way was to build a special platform solution.

4.1 System Requirements

Main business requirements from the analysis perspective that form a base for platform business logic and user interface design are: all users need to be registered, anonymous access is not allowed; after registration, user fills the profile data and administrator approves it; user profile contains names, contact information, additional information and curricula association [Paper III].

Traineeship requests will be published by students containing general information, and structured data and companies can find the student requests matching their offerings [Paper III]. With the request, the student can apply for traineeship or the lecturer can assign students to request for traineeship and all traineeship applications need to be approved mutually by the student, the company and the lecturer [Paper III].

Traineeship offerings will be published by companies containing general information and structured data where students can find the offerings matching their requests [Paper III]. Students can apply for traineeship offering, or lecturers can assign students request, and all traineeship applications need to be approved mutually by the student, the company and the lecturer [Paper III].

Every traineeship case ends with the feedback given mutually by the student and company whereas feedback contains the questionnaire and competence ratings [Paper III]. Curricula related current competences are associated with student profile, and required competences are associated with traineeship offering [Paper III]. Thus, feedback combines both competence lists [Paper III].

Events will be organized by the lecturer and the company co-operation, for example, company visit, and the published event contains main information and structured data, and it will be approved by the company [Paper III]. Events are shown in the event calendar where students can find interesting events and join them; however, all event participations need to be approved by the lecturer [Paper III].

Traineeship associated documents can be uploaded by the administrator. These documents are associated with meta-data containing general information and structured data to publish specific grouping and sequence [Paper III].

4.1.1 Database and Business Logic Design

Business logic and user interface design principles of the Personnel Involvement Platform are: multi-language, web-based user interface; navigation mainly contains list-card type logic where a chosen list is opened from the main menu item; according to the role rights, it is possible to open current and add new cards from the list; a card opens always in view mode and according to the user rights, it is possible to edit and delete it; all Lists and Cards are shown as tabbed pages where tabs contain additional info related to the active card; from a related info list, it is possible to open once again a related info card and so on; it is everywhere possible to use NAVIGATE button to move one logical level back, it is like intelligent Back button; current action info is shown on the left corner of the main page [Paper III].

The data model is designed as a normalized relational structure without unnecessary data redundancy and by using table triggers, the data integrity is guaranteed [Paper III]. All user interface texts, messages and captions in three languages are stored in the translations table [Paper III].

4.2 Conclusion

Personnel Involvement Platform project was successful, and in the next steps, the usage of this platform will be expanded over the whole university. The aim is to co-operate with other similar projects to integrate and consolidate that kind of web platforms.

Hypothesis 3: "To ensure successful usage of Information Systems or various products and services, in addition to the system design and architecture issues, the implementation and testing process must be paid high attention."

As a representative prototype of testing and implementation of products and services and to consider findings from the KMS Survey, based on current hypothesis, it can be concluded that the most important factor in the uses and gratifications theory is systems usability and content reliability. To ensure successful usage of Information Systems or various products and services, in addition to the system design and architecture issues, the implementation and testing process must receive high attention.

Many well-designed and developed systems are abandoned by the end-users because testing and implementation phases do not get enough attention. Based on UGT approach, consumers personally need to adopt a system on their daily basis activities. Thereby, all the criticism and feedback from end-users is a very valuable information for system developers.

5 Findings and Discussion

Before considering thesis conclusion and its implications, readers should be aware of the limitations of the study. First, the KMS survey consisted of service desk employees from one large call-center company; therefore, the findings may be applicable only to a population that fits these characteristics. Any generalization of these findings to other samples or populations should be made with caution. Second, this study was conducted in the context of knowledge management systems and enterprise resource planning systems integration services, and the results may have been different if the model was applied in another context and with other technologies.

The differentiation with competitors in manufacturing domain will be more and more based on additional digital services (Zacharewicz et al., 2017). These services will be created by gathering and assembling information coming from value chain partners (Zacharewicz et al., 2017). One problem is that partners use different processes, organizations and different enterprise information systems (EIS); which leads to horizontal barriers of interoperability (Zacharewicz et al., 2017).

The different visions of the business process between the enterprise leaders and the developers are still a gap (Zacharewicz et al., 2017). Some barriers persist between these two views of the EIS to implement (Zacharewicz et al., 2017). Thoroughly, one major barrier in EIS interoperability is the matching between the concepts announced in the enterprise models of services by the business responsible and the technical services implemented (Zacharewicz et al., 2017).

The Model Driven Service Engineering Architecture (MDSEA) is proposed in the frame of the Manufacturing SErvice Ecosystem (MSEE) project that defines its first Grand Challenge as making Service Science, Management and Engineering (SSME) evolving towards Manufacturing Systems and Factories of the Future to support service models and service system design and implementation (Zacharewicz et al., 2017).

To achieve interoperability in intra- and inter-organizational processes, there are several aspects to be taken into account when information management systems are developed and implemented. All three previously described cases are playing an important role to achieve expected results. Figure 2.7 shows input and output connections between the cases.

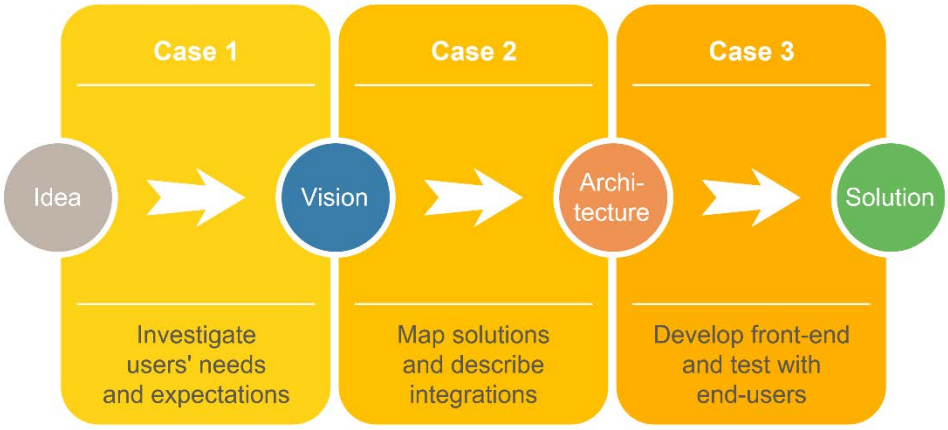

Figure 2.7. Input and output connections between cases.

Investigate users' needs and expectations. Moving from an idea to the vision, it is most important to find out users' needs and expectations. Typically, this step will be done by business process analysis with key users or managers. In this case, the investigated company has implemented few parallel knowledge management solutions over time, and there was no central confidence how to go forward. The solution was to prepare and carry out the survey by using traditional research study methods. Qualitative and quantitative feedback collected in this way from all different employees' levels was very valuable to find out real cause and effect relations and to draw the vision what the company should do next.

Map solutions and describe integrations. From vision to architecture, it is very important to map solutions currently on the market and/or in use and find the best fit gap match with the requirements. Based on today's state-of-the-art paradigm, it should be considered to integrate various solutions or cloud API-s as much as possible and to avoid starting development of the mammoth stand-alone solutions. It is very important to pay attention to integration technologies and fault tolerance issues for the interfaces.

Develop front-end and test with end-users. To develop the solution based on the proposed architecture, it is crucial to choose a platform and technology that will best match the requirements and is sustainable and effective to use. Nowadays, all cloud-based Platform as a Service (PaaS) technologies like Amazon Web Services (AWS) or Microsoft Azure should be the first choice. Usually, the developed front-end brings together information and functionality from different integrated sources and offers a user-friendly overview and search functions together with device optimized ergonomic feedback and operational data entry options.

6 Conclusions and Future Work

Current thesis analyzes interoperability and implementation of information management systems and through three cases summarizes problems and possible solutions. To achieve the thesis objective, the following tasks were accomplished:

- analysis of the Knowledge Management Systems in the world leading IT services corporation;
- analysis of different layers of fault tolerance in the integration interfaces of information systems;
- prototype solution for testing and implementation of products and services to ensure the spread of services.

Knowledge Management Systems survey, which was conducted in a large Service Desk company, points out the following interesting findings:

- time pressure directly causes job stress but has no relation to system usage and operation efficiency;
- operation efficiency is directly influenced by case analyzability and through time efficiency by information system functionality;
- knowledge repository utility is directly influenced by the need to retrieve knowledge and by information system functionality;
- knowledge contribution is related to knowledge repository utility and influenced through satisfaction with knowledge quality by case analyzability and information system functionality.

Anchoring on the uses and gratifications theory, this survey proves the **Hypothesis 1** that Knowledge Management Systems utilization is directly influenced by knowledge quality and ease of access. If several knowledge sources are in use, then KMS utilization can be increased by integrating Electronic Knowledge Repositories and implementing better search functionality. Higher KMS utilization in turn increases knowledge contribution and thereby knowledge quality.

Integration Interfaces of Information Systems are very crucial and the results of the second case indicate that in case of several information systems in use for the same purpose and somewhat overlapping content, instead of replacing those systems with a totally new one, it is more reasonable to develop integrated user interface with a user-friendly search function to aggregate and present data from all the current sources. However, the reliability and fault tolerance of those integration solutions is essential to achieve the value of a complete solution. Therefore, integration interfaces should be built to include isolated levels of fault tolerance:

- service level monitoring;
- process level error handling;
- transaction level exception handling.

This proves the **Hypothesis 2** that efficiency of the knowledge retrieval and contribution processes can be increased through interoperability. Considering the uses and gratifications theory together with machine to machine technology opportunities, integrated systems create a much higher value than standalone systems.

Implementation of Products and Services is a very important factor in the uses and gratifications theory because system reliability, quality and ease of use are main factors that affect the attitudes of users. From the KMS survey findings together with the practical information systems integration and development cases, it can be concluded that systems testing and implementation phases are of the same importance as other phases when building and integrating information systems.

This proves the **Hypothesis 3** that successful usage of information systems or various products and services is ensured by the fact that in addition to the system design and architecture issues, the implementation and testing process must receive high attention.

The novelty of the study lies in the proof of the Uses and Gratifications Theory validity for Enterprise Information Management systems development and implementation. The KMS survey in a large Service Desk company was prepared and published by using all the required standards for a research study and therefore has a marked scientific proof value. For theoretical science, the most influential publication is Paper IV in the International Journal of Information Management, published in cooperation with a foreign research group. All the cases together represent a solution in the interoperability field to develop and implement enterprise information management systems.

In the **further research**, very challenging and state-of-the-art topics are related to developments in artificial intelligence and machine learning areas, which offer a great deal of value for analyzing, integrating and structuring any kind of natural knowledge content. This new paradigm makes it possible to develop self-learning integration interfaces for any kind of source content and thereby build more functional, efficient and extensive interoperability solutions.

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Lühikokkuvõte

Ettevõtte infohaldussüsteemide arendamine ja juurutamine koostalitlusvõime jaoks

Tänapäeva tööstuses vajaminevat väledust ja paindlikkust on võimalik saavutada, kui integreerida töökohad infohalduse protsesside ja süsteemidega ettevõttesiseselt aga ka ettevõtete üleselt, et luua ettevõtete võrgustikke.

Teadmuse haldamine on üks peamisi aspekte, mis on seotud väga erinevate äriprotsesside ja tööülesannetega. Üheks peamiseks küsimuseks on, mil moel teadmuse haldamise protsessid on seoses töö efektiivsuse ja inimkäitumisega. Käesolev doktoritöö uurib teadmuse haldamise süsteemide juurutamise probleeme ja tehnoloogia ning inimkäitumise vaatepunktidest mõjutatud erinevaid aspekte. Peamine fookus on töökoha efektiivsuse ja teadmuse haldamise süsteemide seostel, kus kõige olulisemad tehnilised aspektid on seotud süsteemide omavaheliste integratsioonidega ja kasutatavusega. Kvalitatiivne andmestik probleemipüstituse jaoks ja kvantitatiivne andmestik analüüsi jaoks on kogutud läbi fookusgrupi intervjuude ning veebipõhise küsitluse. Tehnoloogiliste probleemide uurimisel on kasutatud prototüüplahenduste juhtumiuuringuid.

Käesolev doktoritöö adresseerib peamise eesmärgina ettevõttesiseste ja ettevõtete üleste protsesside efektiivsust, läbi teadmuse haldamise koostoime ning infohalduse süsteemide integratsiooni. Eesmärgi saavutamiseks on läbi viidud teadmuse haldamise süsteemide uuring IT teenuseid pakkuva suurkorporatsiooni Põhjamaade tugiteenuse osakonnas, kasutades fookusgrupi intervjuusid ja veebipõhist küsitlust koos praktiliste prototüüp-juhtumitega.

Teadmuse haldamise süsteemide uuring toob välja järgmised huvitavad seosed: ajaline pingelisus mõjutab otseselt tööstressi, aga ei oma seost süsteemide kasutatavuse ega tegevuse efektiivsusega; tegevuse efektiivsus on otseselt mõjutatud juhtumi analüüsitavuse poolt ja läbi ajakasutuse efektiivsuse ka infosüsteemide funktsionaalse kasutatavuse poolt; teadmusbaaside kasutatavus on otseselt mõjutatud vajadusest teadmust hankida ja infosüsteemide funktsionaalse kasutatavuse poolt; teadmuse loomisele kaastöö tegemine on mõjutatud teadmusbaaside kasutatavuse poolt ja läbi teadmuse kvaliteediga rahulolu ka juhtumi analüüsitavuse ning infosüsteemide funktsionaalse kasutatavuse poolt.

Lähtudes teadmuse haldamise süsteemide uuringust välja tulnud seostest koos praktiliste infosüsteemide integratsioonide ning arendamise juhtumiuuringutega, saame peamiselt järeldada, et infosüsteemide kasutatavus, funktsionaalsus ja sisu kvaliteet on peamised mõjutegurid selles, kas inimesed neid süsteeme kasutavad või mitte. Teiseks, kui kasutusel on korraga mitmed erinevad infosüsteemid, mis oma funktsionaalsuse ja sisu poolest teatud osas kattuvad, siis selle asemel, et need süsteemid välja vahetada kolmanda täiesti uue süsteemi vastu, tuleks arendada integreeritud kasutajaliides, mis pakub kasutajasõbralikku otsingufunktsiooni ning presenteerib informatsiooni kõigist olemasolevatest andmeallikatest.

Teadmuse haldamise süsteemide uuring valmistati ette ja viidi läbi lähtudes kõigist teadusuuringu jaoks ette nähtud standarditest ning omab seetõttu teaduslikku tõestusväärtust. Käesoleva doktoritöö kõik juhtumiuuringud kokku moodustavad täieliku lahenduse, et koostalitluse valdkonnas arendada ja juurutada infohalduse süsteeme.

Abstract

Development and Implementation of Enterprise Information Management Systems for Interoperability

Agility and flexibility required in today's production can be achieved by integrating workplaces with information management processes and systems inside a company as well as creating networks of companies.

Knowledge Management is one of the key aspects associated with various business processes and job tasks. The main question is - how knowledge management processes and systems are associated with work efficiency and human behavior. This thesis research analyzes Knowledge Management Systems (KMS) implementation issues and different related technological aspects as well as the viewpoints of the uses and gratifications theory. Main focus is on the work efficiency related to KMS tools where most important technical aspects are integration interfaces between various systems and systems usability. Qualitative data for problem statement and analyzing quantitative data were collected by focus groups and web survey. Technological issues were investigated by prototyped cases.

As the main objective, the efficiency of intra- and inter-organizational processes is addressed by knowledge collaboration and information management systems integration. To achieve the objective, an analysis of Knowledge Management Systems focus groups and a web survey in the Nordic Service Desk Department of a world leading IT services corporation was performed together with practical prototyped cases.

KMS survey points out the following interesting findings: time pressure directly causes job stress but has no relation to system usage and operation efficiency; operation efficiency is directly influenced by case analyzability and through time efficiency by information system functionality; knowledge repository utility is directly influenced by a need to retrieve knowledge and by information system functionality; knowledge contribution is related to knowledge repository utility and influenced through satisfaction with knowledge quality by case analyzability and information system functionality.

From the KMS survey findings together with the practical IS integration and development cases, we can mainly conclude that information system usability, functionality and content quality are playing the main role whether people use it or not. Secondly, if there are several information systems in use for the same purpose and somewhat overlapping content, then instead of replacing those systems with a totally new one, it is more reasonable to develop integrated user interface with a user-friendly search function to collect and present data from all the current sources.

KMS survey was prepared and published by using all required standards for a research study and therefore has scientific proof value. All the cases together represent a complete solution for interoperability field to develop and implement enterprise information management systems. State-of-the-art topics for the further work are related to developments in artificial intelligence and machine learning areas, which offer a great deal of value with analyzing, integrating and structuring any kind of natural knowledge content.

Appendix

Paper I

Lemmik, R., Otto, T., Küttner, R. (2014). Knowledge management systems for service desk environment. *Proceedings of the 9th International Conference of DAAAM Baltic Industrial Engineering*, 139−144.

9th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING"
24-26 April 2014, Tallinn, Estonia

KNOWLEDGE MANAGEMENT SYSTEMS FOR SERVICE DESK ENVIRONMENT

Lemmik, R.; Otto, T.; Küttner, R.

Abstract: *Current paper is based on Knowledge Management Systems (KMS) improvement project in cooperation between Tallinn University of Technology (TUT) and Nordic Service Desk (SD) department of a world leading IT services corporation. The project was initiated to analyze the current KMS at SD department and to propose improvement suggestions.*

Nordic SD department is using KMS in daily activities providing customer support for various international customers where SD activities are managed and coordinated by Finland head office however several 1st Level support activities are provided by subsidiaries in Estonia and Poland.

Key words: knowledge management (KM), knowledge management systems (KMS), knowledge sharing, knowledge sourcing, knowledge contribution

1. INTRODUCTION

The rapidly increasing competitiveness in market highlights the importance of design quality, maximizing productivity, multi-company collaboration, optimal price levels and predictability. The main focus of the manufacturer is to innovate, get products to the market faster, reduce errors and increase flexibility. The manufacturers have been continuing to improve their products, information systems developments and management abilities. Because of that in the past years have seen growing investments in the area of product lifecycle management (PLM), enterprise resource planning (ERP), real time monitoring and optimization [1,2,3], and integration technologies of business software and information systems [4].

On the other side in the information age, companies increasingly derive value from intellectual rather than physical assets, and employee knowledge is believed to be a company's most profitable resource. Knowledge management (KM) refers to identifying and leveraging the collective knowledge in an organization to help the organization compete [5], and knowledge management systems (KMS) are designed to allow firms to manage their knowledge resources. Initially, KM approaches focused on knowledge as objects that could be organized to support decision making, and KMS were seen as tools to manage codified knowledge, such that most KM projects were initiated top-down and driven by management. However, the rigid structure of such centrally controlled KM initiatives often exhibited poor incentives to the sharing and reuse of knowledge [6].

Over the past decade, researchers and managers have investigated methods for improving organizational performance by providing employees with better ways of accessing one another's knowledge. Such knowledge management (KM) efforts often rely on information technologies (IT), including one important class of KM initiatives that employ IT-based repositories, to capture employees' knowledge and make it available to a broad range of potential recipients. Although knowledge repositories have generated significant benefits for some organizations,

research suggests that many repositories fail to enhance knowledge transfer [7].

To succeed, a repository must contain knowledge that will prove useful for employees looking for answers to their questions and solutions to their problems. The task of ensuring the quality of knowledge in a repository often falls to subject matter experts who filter employees' contributions, rejecting those that are redundant, incorrect, ineffective, outdated, or otherwise unhelpful. Without such a validation process, a repository "soon overflows with knowledge assets of questionable value" and can, as a result, lose its credibility with employees [7].

2. PROJECT DESCRIPTION

Current project has a good opportunity to deliver Win-Win solution and to strengthen cooperation with industries and universities. Project scope is limited with analysis document as the main deliverable and no development work is provided. The main objectives are:

- Improvement of KMS
- Decrease ticket solving time
- Increase ticket solving quality

2.1. Project Phases

Describe the current KMS situation:

- Focus groups with KMS end-users
- Per focus group on-site interview
- Prepare survey to be distributed to all SD 1st Level employees

Analyze the usability of the current KMS

- Analyze the data collected during focus groups and survey
- Conclusions from business viewpoint

Improve the usability of the KMS

- Investigate the design and architecture of KMS tools
- Propose the improvement suggestions of KMS tools

2.2. Focus Group Interviews

Aspects in focus:

- Knowledge Type
- Source/Channel of Knowledge
- Knowledge Quality
- Knowledge Sharing
- Routine / Solution Reuse
- Communication Space
- Stress Level
- System Use
- IT Alignment
- Productivity
- Customer Satisfaction

Focus Groups:

- 1st Level SD employees in Estonia, 3-5 focus groups, 8 people each
- 24/7 SD employees in Finland, 2 focus groups, 4 people each
- 2nd Level SD employees in Finland, 1 focus group, 4 people

3. RESEARCH MODEL

The main focus of this paper is to describe theoretical research work which was carried out for the project to compose preliminary research model and to publish the survey.

3.1. Constructs

Constructs are based on and composed according to the research publications mainly from last 5 - 6 years on the KMS field. According to the keyword search near 100 papers were investigated and 15 of them have been directly used as references for the constructs.

Construct Name	Category	Unit of Analysis	Type of Variable	ID
Current location	Background	Individual	Control	C1-1
Current team	Background	Individual	Control	C1-2
Current position	Background	Individual	Control	C1-3
Experience in current position	Background	Individual	Control	C1-4

Experience in area of work	Background	Individual	Control	C1-5
Age	Background	Individual	Control	C1-6
Gender	Background	Individual	Control	C1-7
Work expertise [7]	Background	Individual	Control	C1-8
Training [8]	Environment	Individual	Control	C2-1
Job stress level [9]	Environment	Individual	Independent	C2-2
Time pressure [10]	Environment	Ind. / Case	Independent	C2-3
Case analyzability [11,12]	Environment	Case	Independent	C2-4
Case variability [13,14]	Environment	Case	Independent	C2-5
Satisfaction with quality of knowledge [7]	Environment	Individual	Mediator	C2-6
Sourcing from colleagues [10]	Process	Individual	Dependent	C3-1
Sourcing from local documents [10]	Process	Ind. / System	Dependent	C3-2
Knowledge contribution [15,16,17]	Process	Individual	Dependent	C3-3
Simplicity of information update functionality	Process	System	Independent	C3-4
Information update autonomy [7]	Process	System	Independent	C3-5
Frequency of accessing channel of knowledge [7]	Systems	Individual	Mediator	C4-1
Simplicity of search functionality	Systems	System	Independent	C4-2
Search results presentation	Systems	System	Independent	C4-3
Sourcing from repository [10]	Systems	Ind. / System	Dependent	C4-4
Time efficiency of retrieving knowledge [18,19]	Systems	System	Mediator	C4-5
Time efficiency of storing knowledge [18,19]	Systems	System	Mediator	C4-6
Operation efficiency [20]	Outcomes	Individual	Dependent	C5-1
Operation performance [20]	Outcomes	Individual	Dependent	C5-2
Customer satisfaction target	Outcomes	Individual	Dependent	C5-3

Table 1. Constructs for Research Model

3.2. Survey Scales

According to scale composing methods it was decided to use six point discrete scales since there is no middle point.

1	Strongly Disagree
2	Disagree
3	Inclined to Disagree
4	Inclined to Agree
5	Agree
6	Strongly Agree

Table 2.1. Consent Scale (Discrete)

1	Never
2	Very Rarely
3	Rarely
4	Occasionally
5	Frequently
6	Very Frequently

Table 2.2. Extent Scale (Discrete)

1	Estonia
2	Finland
3	Poland

Table 2.3. Location (Qualitative)

1	SD
2	SD 24/7
3	Retail
4	UAS
5	GDC SD

Table 2.4. Team Type (Qualitative)

1	UAS Specialist
2	Customer Support Specialist
3	Customer Coordinator
4	Incident Coordinator
5	Group Coordinator
6	Group Manager

Table 2.5. Job Position (Qualitative)

1	Less than 6 months
2	Range of 6 months to 1 year
3	Range of 1 to 2 years
4	Range of 2 to 5 years
5	Range of 5 to 10 years
6	More than 10 years

Table 2.6. Years Range (Qualitative)

1	21 and Under
2	22 to 34
3	35 to 44
4	45 to 54
5	55 to 64
6	65 and Over

Table 2.7. Age Range (Qualitative)

1	Female
2	Male

Table 2.8. Gender (Qualitative)

1	Less than 10%
2	Range of 10% to 30%
3	Range of 30% to 50%
4	Range of 50% to 70%
5	Range of 70% to 90%
6	Range of 90% to 100%

Table 2.9. Percentage (Qualitative)

3.3. Survey Items and Publishing

Survey items were validated by using sorting method to prove that they represent associated constructs.

Web based survey was published only in English language to 400 employees at SD 1st Level. Questionnaire was fully completed by 159 employees which result will be used for the further analysis.

Item / Question	ID	Scale	Result
Your current work location:	C1-1-1	Location	-
Your current team:	C1-2-1	Team Type	-
Your current position in the team:	C1-3-1	Job Position	-
How long have you been employed in the current position?	C1-4-1	Years Range	-
How long have you been working in the current area of work (including previous companies, if applies)?	C1-5-1	Years Range	-
Your age range:	C1-6-1	Age Range	-
Your gender:	C1-7-1	Gender	-
I am an expert in solving customer's technical problems.	C1-8-1	Consent	4,9
I am an expert in technical troubleshooting.	C1-8-2	Consent	4,8
To what extent are training activities available for new employees?	C2-1-1	Extent	3,9
To what extent do training programs exist?	C2-1-2	Extent	3,8
To what extent is there too much trouble at work?	C2-2-1	Extent	3,9
To what extent is there too much work to handle?	C2-2-2	Extent	4,2
To what extent is there pressure on SD employees?	C2-2-3	Extent	4,3
I have limited amount of time to complete my work.	C2-3-1	Consent	4,0
Many employees at my level are overwhelmed by time-limitations to solve cases.	C2-3-2	Consent	4,0
To what extent is there a clearly known way to solve a case?	C2-4-1	Extent	4,5
To what extent are there precise instructions that can be followed when solving cases?	C2-4-2	Extent	4,3
To what extent are there common practices to work on cases?	C2-4-3	Extent	4,3
I frequently deal with non-routine cases.	C2-5-1	Consent	4,4
The cases I work on involve answering questions that have not been asked in that way before.	C2-5-2	Consent	4,3
The content in KMS meets my needs.	C2-6-1	Consent	3,7
I am satisfied with the content in KMS.	C2-6-2	Consent	3,6
The overall quality of content in KMS is high.	C2-6-3	Consent	3,5

To what extent do you discuss problems with colleagues when you need to improve your knowledge on a topic or issue related to work?	C3-1-1	Extent	4,9
When you work on a challenging case, to what extent do you communicate with your colleagues who may have encountered similar issues?	C3-1-2	Extent	5,1
When you work on a case, to what extent do you refer to local documents stored outside the KMS?	C3-2-1	Extent	4,4
To what extent do you get useful knowledge for solving cases by reading local documents other than articles in KMS?	C3-2-2	Extent	4,2
To what extent are you contributing knowledge to KMS?	C3-3-1	Extent	3,2
Updating content into KMS is simple.	C3-4-1	Consent	3,7
When contributions are submitted to KMS, they are usually validated.	C3-5-1	Consent	3,8
Getting contributions to KMS approved and accepted is easy.	C3-5-2	Consent	3,9
In the past month, to what extent did you access KMS?	C4-1-1	Extent	3,7
Searching for content in KMS is simple.	C4-2-1	Consent	3,7
The results of search in KMS are presented in an appropriate way.	C4-3-1	Consent	3,6
To what extent do you use KMS to acquire knowledge?	C4-4-1	Extent	3,6
When you work on a challenging case, to what extent do you look in KMS to find solutions to similar cases?	C4-4-2	Extent	3,6
Retrieving content from KMS happens in a time-efficient manner.	C4-7-1	Consent	3,6
Retrieving content from KMS happens on time in order to solve case.	C4-7-2	Consent	3,7
Storing content in KMS happens in a time-efficient manner.	C4-8-1	Consent	3,7
When storing content in KMS as planned, it happens in a time-efficient manner.	C4-8-2	Consent	3,7
To what extent are you able to operate efficiently?	C5-1-1	Extent	4,8
How many cases did you solve last month?	C5-2-1	Integer	262
With respect to the cases that you solved last month, what percentage were closed during the first call?	C5-2-2	Percentage	-
What was the average customer satisfaction level you achieved last month?	C5-3-1	Decimal (Continuous)	9,2 of 10

Table 3. Survey Items and average figures

4. CONCLUSION

Survey results of the current project phase together with preliminary research model based on constructs will be input for the next project phase where the statistical analysis is done. According to the results from statistical analysis in the final project phase the research model is validated and project conclusions will be drawn.

5. ACKNOWLEDGEMENTS

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Paper II

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FAULT TOLERANCE IN INTEGRATION INTERFACES OF BUSINESS SOFTWARE

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ABSTRACT

Current paper describes different integration technologies of business software to analyze fault tolerance and reliability of those interfaces. Main focus is on the ERP (Enterprise Resource Planning) software Microsoft Dynamics NAV, which can be integrated with other business applications as central business data source. To highlight real-life situations the sample integration project is used as a case-study, where different fault tolerance levels are used for integration interfaces.

Keywords: Integration Interfaces, Fault Tolerance, Business Software, Enterprise Service Bus, Web Services

1. INTRODUCTION

The rapidly increasing competitiveness in market highlights the importance of design quality, maximizing productivity, multi-company collaboration, optimal price levels and predictability. The main focus of the manufacturer is to innovate, get products to the market faster, reduce errors and increase flexibility. The manufacturers have been continuing to improve their products, information systems developments and management abilities. Because of that in the past years have seen growing investments in the area of product lifecycle management (PLM) [1, 2], enterprise resource planning (ERP), real time monitoring and optimization [3,4], and integration technologies of business software and information systems [5].

On the other side there are increasing demands to make the application software systems more tolerant to faults. From a user's point of view, fault tolerance has two dimensions: availability and data consistency of the application. For example users of telephone switching systems demand continuous availability, whereas bank teller machine customers demand the highest degree of data consistency [6].

Exception handling is one application level feature to interrupt normal operation to handle abnormal responses. In the context of software fault tolerance, exceptions are signaled by the implemented error detection mechanisms as a request for initiation of an appropriate recovery. The design of exception handlers requires that consideration is given to the possible events triggering exceptions, the effects of those events on the system, and the selection of appropriate mitigating actions [7].

Application level fault tolerance for integration interfaces contains different layers to monitor services and handle exceptions. Automated integration interfaces for ERP software MS Dynamics NAV are mainly based on the NAS (Navision Application Server) windows service which operates a number of server-side background processes. To ensure reliability of those processes the following is required:

- Monitor that NAS service is running by using windows standard monitoring software
- Monitor that NAS service is alive by communicating one specially designed interface
- Global framework for processes to handle unexpected errors to keep processes alive
- Per process error handling in database transaction level for continuous processing
- Per transaction error handling to process through all known exceptions
- Watchdog process to send out notifications about exceptions and error situations
- Provide application user interface to access processing and error logs
- Provide mechanism to make required corrections and initiate recurrent processing

2. APPLICATION LEVEL FAULT TOLERANCE

Availability and data consistency in an application are traditionally provided through fault tolerant hardware and operating system, used by the application for its execution. New trends are emerging in the marketplace that is changing this tradition. Standard commercial hardware and operating systems are becoming highly

reliable, distributed and inexpensive to the extent that they are now off-the-shelf commodity items. New application software systems are increasingly networked and distributed, i.e. mostly client-server systems [6].

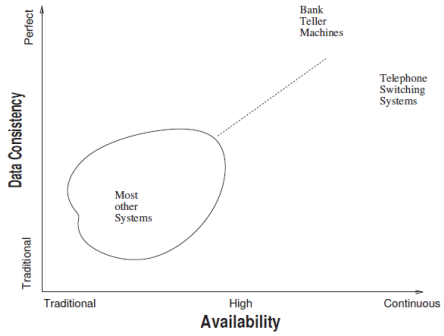

Figure 1. Dimensions of fault tolerance [6]

Many of those applications are also built from reusable components whose sources are unknown to the application developers. Due to this complexity in application software, the proportion of failures due to faults in the application software is increasing. The End-to-End type of arguments implies that one needs fault tolerance in the application software itself to handle such failures [6].

2.1. Application Infrastructure

Hardware level is the lowest level to catch application errors. If an error passed through all the higher levels then it will cause assembler error on microprocessor level and whole system need to be restarted.

Operating System level can catch application errors which haven't been handled at application software or database engine levels. An error at this level can cause restart of the application software or database engine service.

Database Engine level can ensure data consistency per transaction. Database transaction will be initiated and finished by application software and it can contain several data manipulation actions. If application software dies or loses database connection during the transaction then database engine can automatically initiate rollback for whole transaction after transaction timeout was occurred to avoid inconsistent data state.

Application Software level error handling can detect erroneous processes and kill them to continue with other processes if possible. In some situations this level can cause that application continues working in abnormal state and finally can collapse and need to be restarted.

2.2. Application Exception Handling

Exception handling level is the best level for reliable error handling to avoid errors handled at infrastructure level. This level is highly application business logic specific and can react more adequately for errors than infrastructure level. On the other hand it is also more costly to build very deep error handling at this level because of each upper layer at this level can be less unified and will be more business logic specific.

Try/Catch methods should be used to enclose some sort of business logic to catch irregular or unexpected errors to handle those and continue processing as defined. This layer can try to repeat some function several times if an error was irregular or if it was associated with some external problem like network errors etc. Also it is possible to build regular error handling at this layer for known but rare situations where erroneous situation can be skipped or function can be cancelled with error message.

If/Then methods are highly application business logic specific and should be used in situations if there are different alternative workflows possible for exceptional cases. Also this layer is commonly used to validate data input according to the data validation rules.

User Interface layer is the highest application layer which can be used for basic data validation to avoid processing of invalid data input and to output instant warnings or error messages for user.

3. APPLICATION INTEGRATION INTERFACES

SOA is concerned with the independent construction of services which can be combined into meaningful, higher level business processes within the context of the enterprise.

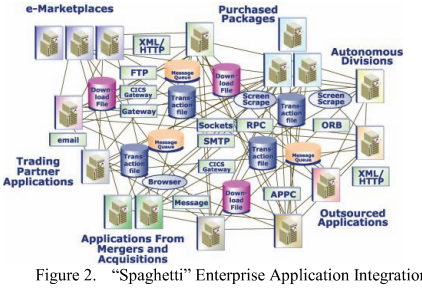

Figure 2. "Spaghetti" Enterprise Application Integration [8]

Typical "Spaghetti" Enterprise Application Integration where adapters interface with applications at their integration points is presented in Figure 2.

A Service Oriented Architecture presented in Figure 3 describes several aspects of services within an enterprise application: [8]

- The granularity and types of services
- How services are constructed
- How the services communicate at a technical level
- How the services are combined together (i.e. orchestrated)
- How the services interoperate at a semantic level (i.e. how they share common meanings)
- How services contribute to IT and Business Strategy

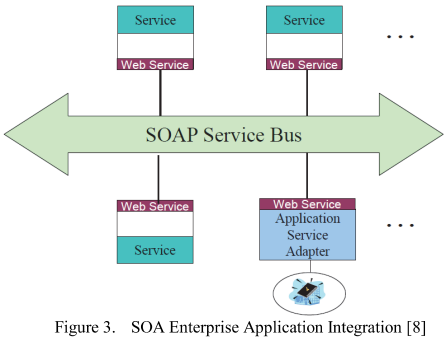

Figure 3. SOA Enterprise Application Integration [8]

Based on SOA the special Service Oriented Integration (SOI) methodology is evolved:

- An architectural and technology based approach to exposing and integrating existing applications as services
- Builds on EAI technology, using new Web services based platforms
- Exposes services to a bus, not point-to-point
- Extends SOA to integration solutions

Benefits of SOI Approach presented in Figure 4. [8]

- Each system is integrated once into the service bus, rather than many time for each point-to-point connection
- Multiple services can be easily constructed from the integration of existing applications
- New processes can be constructed from the service
- Layered SOI approach enables quickly reconfiguring processes or services without needing to change operational systems
- Layered SOI approach allows operational systems to change without affecting business processes

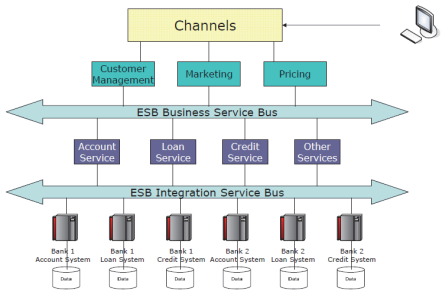

Figure 4. SOI Enterprise Application Integration [8]

The Enterprise Service Bus (ESB) provides an ideal platform for SOI applications and SOI combines Web service, EAI and SOA.

3.1. Three-Tier Architecture

The three-tier architecture model, which is the fundamental framework for the logical design model, segments an application's components into three tiers of services. These tiers do not necessarily correspond to physical locations on various computers on a network, but rather to logical layers of the application. How the pieces of an application are distributed in a physical topology can change, depending on the system requirements [9].

The presentation tier, or user services layer, gives a user access to the application. This layer presents data to the user and optionally permits data manipulation and data entry. The two main types of user interface for this layer are the traditional application and the Web-based application. Web-based applications now often contain most of the data manipulation features that traditional applications use. This is accomplished through use of Dynamic HTML and client-side data sources and data cursors [9].

The middle tier, or business services layer, consists of business and data rules. Also referred to as the business logic tier, the middle tier is where developers can solve mission-critical business problems and achieve major productivity advantages. The components that make up this layer can exist on a server machine, to assist in resource sharing. These components can be used to enforce business rules, such as business algorithms and legal or governmental regulations, and data rules, which are designed to keep the data structures consistent within either specific or multiple databases. Because these middle-tier components are not tied to a specific client, they can be used by all applications and can be moved to different locations, as response time and other rules require. For example, simple edits can be placed on the

client side to minimize network round-trips, or data rules can be placed in stored procedures [9].

The data tier, or data services layer, interacts with persistent data usually stored in a database or in permanent storage. This is the actual DBMS access layer. It can be accessed through the business services layer and on occasion by the user services layer. This layer consists of data access components (rather than raw DBMS connections) to aid in resource sharing and to allow clients to be configured without installing the DBMS libraries and ODBC drivers on each client [9].

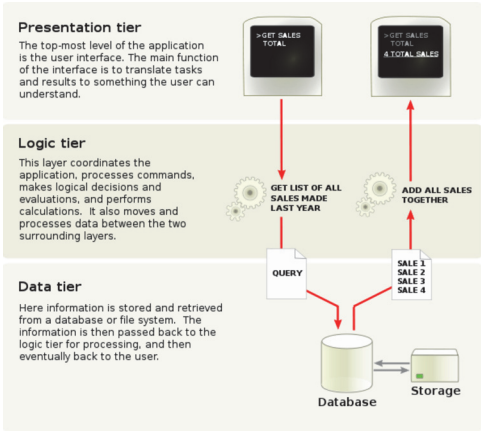

Figure 5. Three-tier application [9]

During an application's life cycle, the three-tier approach provides benefits such as reusability, flexibility, manageability, maintainability, and scalability. You can share and reuse the components and services you create, and you can distribute them across a network of computers as needed. You can divide large and complex projects into simpler projects and assign them to different programmers or programming teams. You can also deploy components and services on a server to help keep up with changes, and you can redeploy them as growth of the application's user base, data, and transaction volume increases. [9]

3.1.1. Database tier integration

Database level integration interfaces were common in Two-Tier applications where business logic was mostly located at database level. This integration level is based on database tables, views and stored procedures and integrated applications will connect directly into each other databases to query and manipulate the data.

For applications with Three-Tier architecture this level isn't often used for integration because of the database level doesn't contain any more business logic and it's easy to break data consistency by manipulating data directly at database level. As well the technology of the integration interface at this level is database engine specific and there can be several complexity or compatibility issues between different platforms.

3.1.2. Middle tier integration

For applications with Three-Tier architecture this level is commonly used to build integration interfaces. Actually there isn't big difference at all to provide Middle Tier services for its own presentation layer or for some other application. As integration technology the SOAP Web Services are commonly used at this level which are mostly cross-platform compatible and widely supported.

SOAP Version 1.2 (SOAP) is a lightweight protocol intended for exchanging structured information in a decentralized, distributed environment. It uses XML technologies to define an extensible messaging framework providing a message construct that can be exchanged over a variety of underlying protocols. The framework has been designed to be independent of any particular programming model and other implementation specific semantics. The ability to use SOAP in a particular environment will vary depending on the actual constraints, choice of tools, processing model, or nature of the messages being exchanged. SOAP has been designed to have a relatively small number of dependencies on other XML specifications, none of which are perceived as having prohibitive processing requirements. Also, limiting use of SOAP to small messages instead of arbitrarily-sized messages and supporting only a few specific message types instead of implementing generalized processing could significantly lower processing requirements [10].

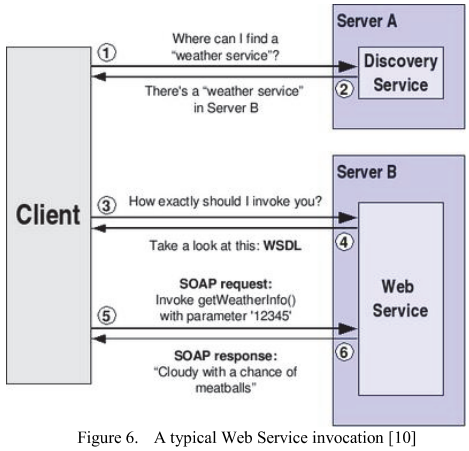

Figure 6. A typical Web Service invocation [10]

As communications protocols and message formats are standardized in the web community, it becomes increasingly possible and important to be able to describe the communications in some structured way. WSDL addresses this need by defining an XML grammar for describing network services as collections of communication endpoints capable of exchanging messages. WSDL service definitions provide documentation for distributed systems and serve as a recipe for automating the details involved in applications communication. A WSDL document defines services as collections of network endpoints, or ports. In WSDL, the abstract definition of endpoints and messages is separated from their concrete network deployment or data format bindings. This allows the reuse of abstract definitions: messages, which are abstract descriptions of the data being exchanged, and port types which are abstract collections of operations. The concrete protocol and data format specifications for a particular port type constitute a reusable binding. A port is defined by associating a network address with a reusable binding, and a collection of ports define a service [11].

3.1.3. Presentation layer integration

Integration interfaces at presentation layer were more often used in Two-Tier applications where data validation rules were mostly located at this level. Integration interfaces at presentation layer can treat more like data export tools and data mass manipulation tools above of the application user interface. As integration technology CSV or Excel file import/export is commonly used at this integration level.

For applications with Three-Tier architecture this level is used in modern user interfaces to support simple copy/paste data transfers between application software and office software e.g. Microsoft Excel and Microsoft Word. Commonly data export from application software towards office software is supported and also sometimes data transfer back from office software is supported as well.

3.2. Microsoft Dynamics NAV

Microsoft Dynamics NAV is an enterprise resource planning (ERP) software product from Microsoft. The product is part of the Microsoft Dynamics family, and intended to assist with finance, manufacturing, customer relationship management, supply chains, analytics and electronic commerce for small and medium-sized enterprises. Value-added resellers (VAR)s can have full access to the business logic source code, and it has a reputation as being easy to customize. For modifications of the system, the proprietary programming language C/AL is used. [12]

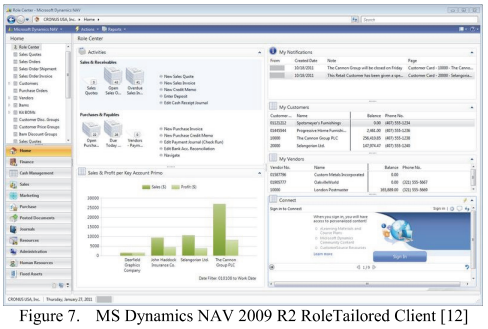

Figure 7. MS Dynamics NAV 2009 R2 RoleTailored Client [12]

The product itself has gone through several name changes as the original Navision Company or Microsoft has tried to decide on how it should be marketed. The names "Navision Financials", "Navision Attain", "Microsoft Business Solutions Navision Edition", and the current "Microsoft Dynamics NAV" have all been used to refer to this product. In December 2008 Microsoft released Dynamics NAV 2009, which contains both the original "classic" client, as well as a new three-tier GUI called the RoleTailored Client (RTC). Microsoft originally planned to develop an entirely new ERP system (Project green), but has decided to continue development of all ERP systems (Dynamics AX, Dynamics NAV, Dynamics GP and Dynamics SL). All four ERP systems will be launched with the same new role based user interface, SQL based reporting and analysis, SharePoint based portal, Pocket PC based mobile clients and integration with Microsoft Office. [12]

Relative to Microsoft's other 3 ERP products, Dynamics NAV's sector is distribution and manufacturing companies that want more than "out of the box" functionality. The solution has a standard feature set, but it can also be thought of as an "ERP System construction set". The Pascal-like development language is easily accessible to appropriate developers and is designed for rapidly customizing the software. There is no need for complex server side Transact-SQL stored procedures as the one language manages the application and database. [12]

According to Microsoft, Dynamics NAV is being used by approximately 65,000 companies, with over 1.3 million end user licenses. Approximately 13,000 of those companies are in the US. It was the first and only mid-market ERP application to break one-million end user licenses. Microsoft Dynamics NAV delivers integrated functionality to provide support for: [12]

- Financial management
- Supply chain management
- Manufacturing

- Distribution
- Customer relationship management
- Sales and marketing
- Service management

With Microsoft Dynamics NAV 2009, the architecture has changed from a two- to three-tier architecture, enabling the new RoleTailored client and Web services. Web services are a standard widely used method for integrating applications and are supported in Microsoft Dynamics NAV 2009. By implementing Web services, you can access Microsoft Dynamics NAV data and business logic from outside the product in a standard, secure way. This enables you to connect Microsoft Dynamics NAV to other systems within an organization. [12]

4. EAS CASE STUDY

As a case study in current paper one NAV project is described where NAV is implemented as a central IT solution of the organization and it has lot of internal and external integration interfaces with other applications and IT systems. It's highly customized solution developed for Enterprise Estonia (EAS) to cover all the main business processes in the organization.

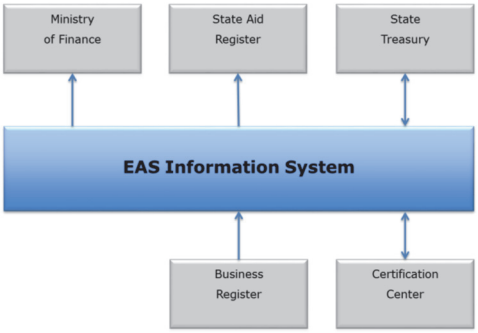

Figure 8. External Integration

Due to the solution has been developed and grown during 8 years there are used different architectural and technological solutions. Main external integrations are:

- Ministry of Finance – SOAP Web Services
- State treasury – X-Road Web Services
- Business Register – Direct XML Interface
- Certification Center – SOAP and COM Library

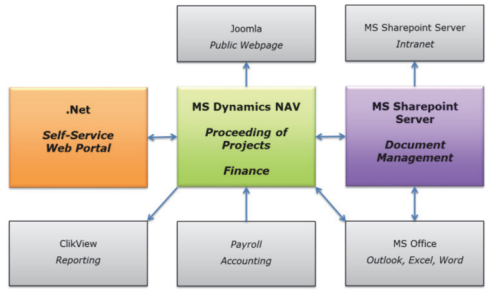

Figure 9. In-House Integration

There are three main parts that IT system consists and which are deeply integrated with each other in-house by using following technologies:

- MS Dynamics NAV as central processing solution
  - SOAP Web Services
  - X-Road Web Services
  - Direct XML Interface
  - Windows COM Library
  - Microsoft Message Queuing
  - Database Views and Stored Procedures
  - CSV file import/export
- MS SharePoint as document management system
  - SOAP Web Services
  - Database Views and Stored Procedures
- .NET Web Portal as Customer Self-Service Centre
  - SOAP Web Services
  - Microsoft Message Queuing

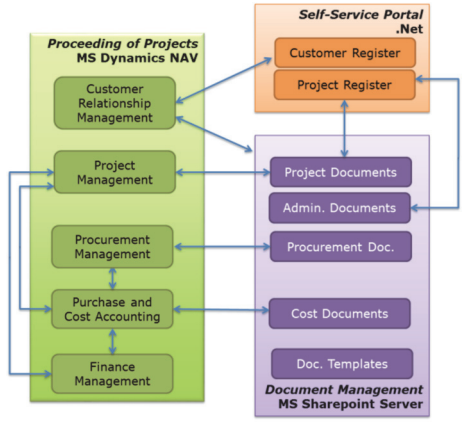

Figure 10. Integration between modules

All of those three main parts can be divided into modules which have internal integrations with each other. Following main functional areas are covered:

- Customer Relationship Management (CRM)
- Proceeding of Projects (PAM)
- Procurement Management
- Processing of Purchase Invoices
- Finance Management

As it is very complex and extensive IT solution which covers very critical business areas it needs reliable error and exception handling solutions for the integration interfaces.

Error handling and monitoring of those interfaces is divided into several levels to acquire optimal combination of reliability and cost efficiency.

4.1. Service Level Monitoring

This level is used to keep middle tier services running and alive in any unexpected error situations. Normally working system shouldn't cause any errors at this level and all the errors occurred this level need to be analyzed case by case to avoid them at the future.

- Monitor that NAV services are running by using windows standard monitoring software. Service states and error messages are logged to Windows Event Log.
- Monitor that NAV services are alive by communicating them periodically through specially designed interface. Service states and error messages are logged to Windows Event Log.
- Monitor Windows Event Log messages by using windows standard monitoring software. According to specified message type and importance initiate specified notifications or actions.
- If service has stopped then try to restart it. If automatic restart fails then send out system critical state notification to administrators.
- Send out non-critical notifications about occurred error and warning situations to maintenance team.
- If an error at this level occurred during integration process e.g. during SOAP request then process terminates and integration interface can't send out any response. This means that other system needs to wait until timeout occurs.

4.2. Process Level Error Handling

This level is used to catch known but rare errors which don't need to be handled according to the business logic. This level has unified design by using try/catch methods to enclose all processes. If error occurs then service is skipping erroneous process and will continue with next processes. In the situation where erroneous process was preceded for some next process the next process probably will get the transaction level error. Errors occurring at this level commonly are associated with invalid web service request or invalid input data. Responses sent out at this level are mainly general error messages e.g. SOAP protocol errors.

- Main part at this level is global and unified framework for processes to handle errors to keep services running and alive. Commonly this framework uses try/catch methods to enclose processes.
- Error handling is process-oriented with the purpose to not affect other processes. If multiple processes are connected at business logic level then those relations aren't identified.
- Main purpose at this level is to skip erroneous processes and continue with next processes and to avoid infinite loops of the erroneous process.
- Global error logging into application level error logs to analyze errors and if necessary then manually initiate recurrent processing.
- Send out notifications according to message types and importance settings.
- If an error at this level occurred during integration process e.g. during SOAP request then unhandled exception or SOAP protocol error response will be sent out.

4.3. Transaction Level Exception Handling

Exception handling at this level is most advanced and costly but also most important to keep system running smoothly and reliably. This level contains exception handling rules at the business logic layer by using if/then methods. All known possible exception situations are handled by using alternative workflows. It means that exceptions aren't just skipped but some alternative way on workflow can be used to continue positive processing of the transaction. All known and possible error situations can also initiate some alternative workflow or also cancel the transaction with predefined error codes. Errors and exceptions at this level commonly are associated with data quality and data validation rules according to associated business logic. Responses sent out at this level are predefined and detail error messages which can be associated as well with the other systems business logic and workflows to define how to proceed most adequately in the situation where an error was occurred at this level.

- Error handling is transaction-oriented to process through all known exception situations without affecting other transactions in the same process.
- This level is based on business rules and alternative workflows defined for all possible known error and exception cases.
- Transaction specific issue logging into application level error logs to analyze cases and if necessary then

make data corrections and initiate recurrent processing.
- Send out notifications according to message types and importance settings.
- If an error at this level occurred during integration process e.g. during SOAP request then response with predefined error/status code will be sent out to integration interface.

4.4. User Level Intervention

This level is used for corrective and preventive actions to maintain the system and initiate system improvement tasks to avoid recurring cases hereafter.

- Provide user level mechanisms to react for notifications.
- Provide application level user interface to access all processing and error logs.
- Provide mechanism to make necessary data corrections and initiate recurrent processing.
- If process level error handling fails for some reason then terminate abnormal or looping processes.
- Continuously analyze occurred issues and initiate system improvement tasks.

5. CONCLUSION

In conclusion the error handling for integration interfaces is very important to build reliable and fault tolerant solutions. Compared to application user interfaces, where human can react for error situations creatively the integration interfaces without error handling will just stop working or continue working at inconsistent or looping state which can cause lot of problems. In worst cases also data damages or massive data avalanche or spamming can occur.

Very critical is to divide error handling into described levels adequately and reasonably. It is important to avoid service level errors in any case. To make decisions between process and transaction levels. It's important to calculate optimal cost efficiency because of the transaction level is most costly, however process level is sometimes too broad.

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Paper III

Lemmik, R., Karjust, K. (2012). Interoperability between different interest groups - practice portal case study. *Proceedings of the 8th International Conference of DAAAM Baltic Industrial Engineering*, 169−174.

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INTEROPERABILITY BETWEEN DIFFERENT INTEREST GROUPS PRACTICE PORTAL CASE STUDY

Lemmik, R.; Karjust, K.

Abstract: *Interoperability is a property referring to the ability of diverse systems and organizations to work together (inter-operate). To achieve interoperability between different organizations or interest groups, one possible way is to build specific web portals where structured information can be easily published and consumed. Current work describes the solution where traineeship mediation process was organized through Practice Portal in TUT Faculty of Mechanical engineering. There are different Interest groups associated with the portal: Students – publish their traineeship requests and join traineeship events; Companies – publish their traineeship offerings and organize traineeship events; Lecturers – represent students or companies in certain situations; Curators – collect the information and manage traineeship.*

To meet the needs of those interest groups the development project was launched to specify all traineeship processes in TUT Faculty of Mechanical engineering and according to those processes build specific web portal. Current paper focuses to the following aspects during this project: Analysis – how to find out all requirements; Design – how to structure requirements from IT solution viewpoint; Develop – how to find proper technical architecture; Implement – how to go live and involve all interest groups to use the solution.

Key words: interoperability, CRM, diverse system, practice portal, database

1. INTRODUCTION

Web technologies offer the opportunity for our colleges and universities to move from having a historic focus on processes to being information- and communications-based institutions [1].
The customer is rightfully the center of the university information model. Unlike many commercial enterprises, with simple client provider relationships, universities have a complex set of relationships with a wide variety of constituents. In fact, the term customer is misleading in a university context. We are using customer to mean the full community of individuals who have a relationship with our institution. Institutionally we tend to think in terms of separate categories for each of these relationships and separate institutional departments to service them [1,2].

1.1. Customer Relationship Management

CRM is both a business strategy and a set of discrete software tools and technologies, with the goal of reducing costs, increasing revenue, identifying new opportunities and channels for expansion, and improving customer value, satisfaction, profitability, and retention. CRM focuses on automating and improving the institutional processes associated with managing customer relationships in the areas of recruitment, communication management and marketing. CRM takes a very customer-centric view of the entire customer life cycle, which means that a CRM business strategy places the customer at the center of the organization's universe. From the

perspective of the customer, a CRM business strategy allows interaction with the college or university from a single entity that has a complete understanding of their unique status [1].

1.2. Web Portals

The World Wide Web continues to be the preeminent application on the Internet because it has regularly reinvented itself. In fact, for most people, the World Wide Web has become synonymous with the Internet. With the introduction of Web portals, the Web is in the process of reinventing itself once again. Portals are not a fad or a new name for something that we've been doing all along. They will turn the Web from an institution-centric repository of information and applications to a dynamic user-centric collection of everything useful to a particular person in a particular role. Instead of a single home page that proclaims identically to all who visit how grand the institution is, portals will give nearly every user a customized, unique Web page [1].

1.3. Practice Portal in TUT

The Practice Portal project was launched in Tallinn University of Technology (TUT) Faculty of Mechanical engineering to cover traineeship recruitment and communication management processes. Compared to the current CRM and Web portal solutions on the market the requirements were more or less specific so the best way was to build its own portal solution. Traineeship recruitment process presented in Fig.1 compared to the regular employee recruitment process contains some specific tasks related with the assignments where university side curator or lecturer is involved to coordinate the recruitment process and to provide approvals.

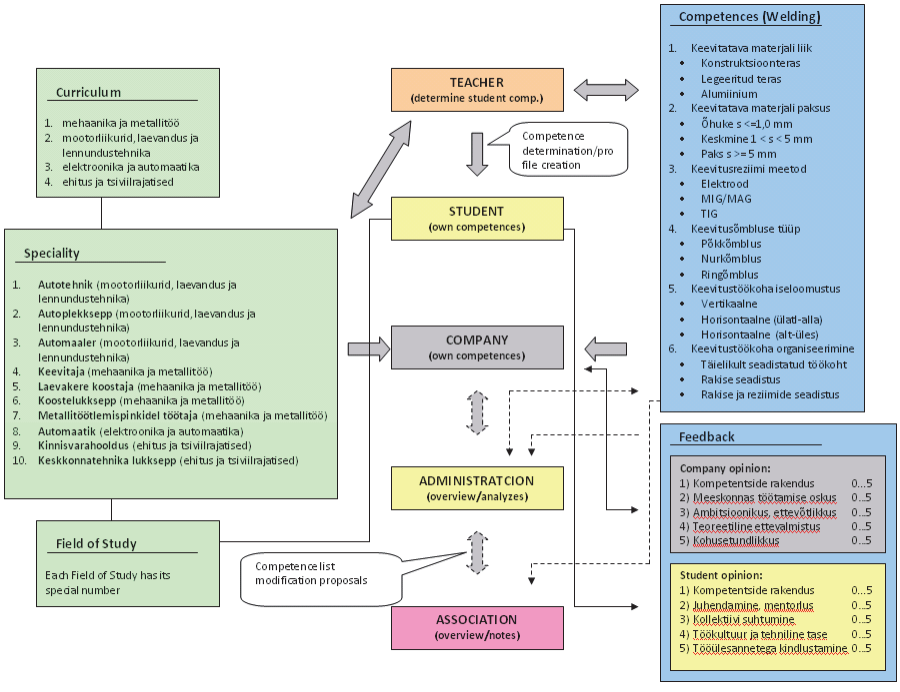

Fig.1. Traineeship recruitment process

2. ANALYSIS

A business process is a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships [3].
Current chapter describes main business requirements from analysis perspective which are base for portal business logic and user interface design.

2.1. Users and roles

All users need to be registered, anonymous access to the portal isn't allowed. After registration user fills the profile data and curator approves it. User profile contains names, contact information, additional information and curricula association. Users can be in following roles:

Student
- Modify profile data
- Post traineeship requests
- Apply for traineeship
- Join to event

Lecturer
- Modify profile data
- On behalf of company post traineeship offerings
- On behalf of student post traineeship request
- Approve traineeship applications
- Post events
- Approve event participation

Company
- Modify profile data
- Post traineeship offerings
- Approve traineeship applications
- Approve events

Curator
- Modify profile data
- Approve profiles
- Post traineeship documents
- Manage portal main data

2.2. Traineeship requests

Traineeship requests will be published by students containing general information and structured data. Companies can find through portal the student requests matching their offerings. With the request student can apply for traineeship or lecturer can assign students request for traineeship. All traineeship applications need to be approved mutually by student, company and lecturer.

2.3. Traineeship offerings

Traineeship offerings will be published by companies containing general information and structured data. Students can find through portal the offerings matching their requests. Students can apply for traineeship offering or lecturer can assign students request. All traineeship applications need to be approved mutually by student, company and lecturer.

2.4. Feedback

Every traineeship case ends with the feedback given mutually by student and company. Feedback contains questionnaire and competence ratings. Curricula related current competences are associated with student profile and required competences are associated with traineeship offering. Feedback combines both competence lists.

2.5. Events

Events will be organized by lecturer and company co-operation, example company visitations. Published event contains main information and structured data and it will be approved by company. Events are shown in event calendar where students can find interesting events and join to them. All event participations need to be approved by lecturer

2.6. Documents

Traineeship associated documents can be uploaded to portal by curator. Documents are associated with meta-data containing general information and structured data to publish specific grouping and sequence.

3. DESIGN

Feature Driven Development (FDD) is an agile and adaptive approach for developing systems. The FDD approach does not cover the entire software development process, but rather focuses on the design and building phases. However, it has been designed to work with the other activities of a software development project and does not require any specific process model to be used. The FDD approach embodies iterative development with the best practices found to be effective in industry. It emphases quality aspects throughout the process and includes frequent and tangible deliveries, along with accurate monitoring of the progress of the project [4].
Current chapter describes business logic and user interface design principles of the Practice Portal presented in Fig.2.

3.1. User interface

Portal has multi-language, web-based user interface. It contains following sections:

- Language selection
- Logged in user info
- Dynamic main menu
- Tabbed main page
- Footer with contact and disclaimer

3.2. Navigation logic

Portal navigation mainly contains list-card type logic where chosen list is opened from main menu item. According to the role rights it is possible to open current and add new cards from list. Card opens always in view mode and according to the user rights it is possible to edit and delete it. All Lists and Cards are shown as tabbed pages where tabs contain additional info related with the active card. From related info list it is possible to open once again related info card and so on. It is everywhere possible to use NAVIGATE button to move one logical level back, it's like intelligent Back button. Current action info is shown on left corner of the main page

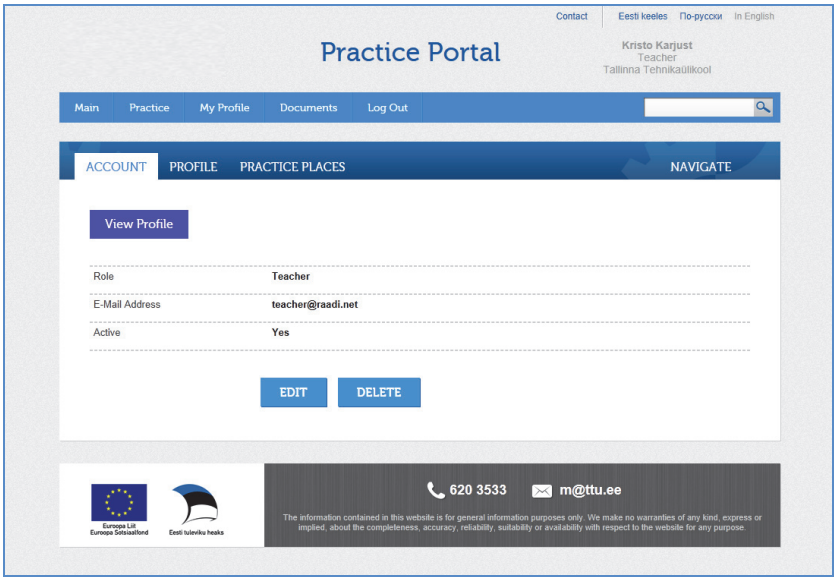

Fig.2. Practice Portal user interface

4. DEVELOPMENT

At the most basic level, the Web works off a client / server architecture. Simply stated, that means that both a central server and a client application are responsible for some amount of processing, presented in Fig.3. Almost all of the work of Web applications takes place on the server. The Web server is responsible for communicating with the browser [5].

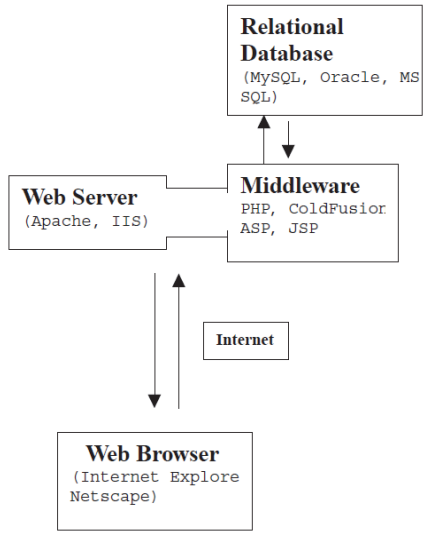

Fig.3. Architecture of Web applications [5]

4.1. PHP programming language

PHP belongs to a class of languages known as middleware. These languages work closely with the Web server to interpret the requests made from the World Wide Web, process these requests, interact with other programs on the server to fulfill the requests, and then indicate to the Web server exactly what to serve to the client's browser [5].

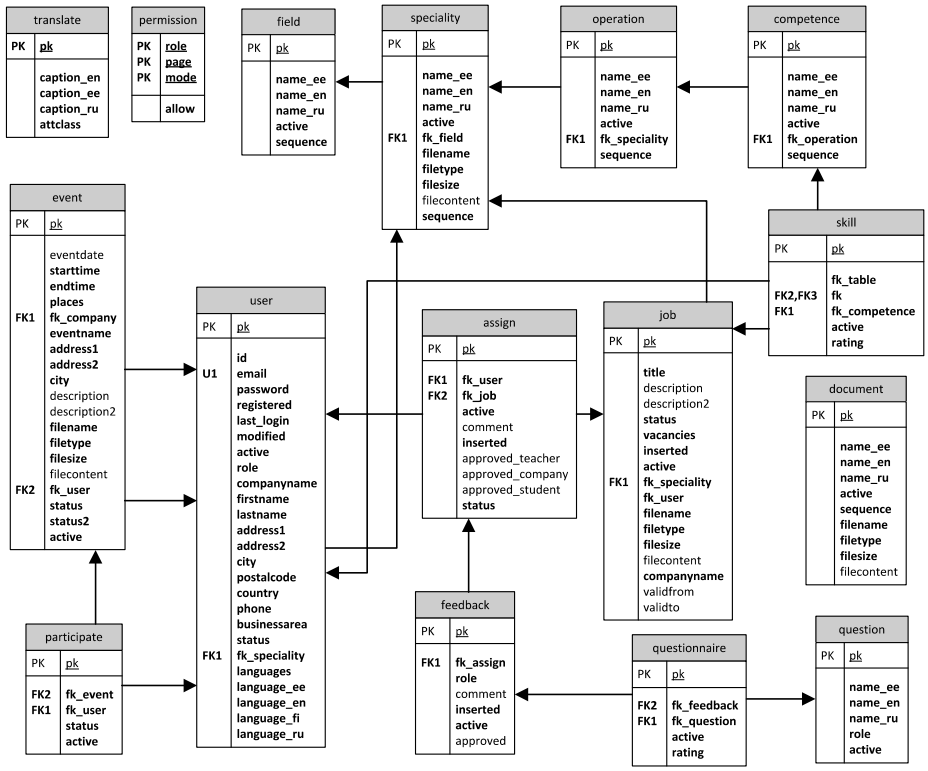

Fig.4. Practice Portal data model

4.2. MySQL database

Relational database management systems (RDBMSes) provide a great way to store and access complex information. All the major databases make use of the Structured Query Language (SQL). Some of the more popular commercial RDBMSes are Oracle, Sybase, Informix, Microsoft's SQL Server, and IBM's DB2. In addition to MySQL, there are now two major open-source relational databases. Postgres has been the major alternative to MySQL in the open-source arena for some time. For a while, Borland released its Interbase product under an open-source license and allowed free download and use [5].

4.3. Practice Portal architecture

In current project PHP and MySQL have been chosen as widespread open-source, freeware and cross-platform components for architectural base.
PHP programming code in current project has been structured as modular as possible which allows easily to expand and improve the application. All kind of hardcoding is avoided i.e. all multi-language captions and user role rights are stored in database and can be easily modified by end-user.
Data model in MySQL database, presented in Fig.4 is designed as normalized relational structure without unnecessary data redundancy. By using table triggers the data integrity is guaranteed.
Multi-language functionality is currently limited with three languages: Estonian, Russian and English. All user interface texts, messages and captions in three languages are stored in translations table. For main data translations, data tables contain three name_xx fields for texts in different languages.

5. CONCLUSION

The project described in current paper was successful in general. The problems were solved during project and can be avoided next time by using experience from current project. Next steps will be to expand the usage of this portal over the whole university and to co-operate with other similar projects to integrate and consolidate this kind of web portals.

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Paper IV

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Does knowledge retrieval improves work efficiency? An investigation under multiple systems use

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ABSTRACT

Organizations encourage active knowledge retrieval from knowledge management systems; however, this does not always lead to higher work efficiency. Anchoring on uses and gratifications theory and psychology of sunk cost, this study investigates knowledge workers' knowledge retrieval behavior and its subsequent impact on their work efficiency under three knowledge management systems, which differ in the creators of the systems and their related contents. Survey and interview data were collected from an IT call-center company. The results show knowledge workers who actively retrieved knowledge from the organization-created system that contains self-created content exhibited higher work efficiency. The results also show they obtained gratifications from actively retrieving knowledge from a self-made system; however, due to the workers' biased perceptions toward that system, knowledge retrieval from a self-made system did not induce higher work efficiency. The findings provide organizations suggestions for designing knowledge management systems and their related contents.

1. Introduction

Even when an organization mandates the use of a specific IT application, individuals retain considerable discretion regarding use of the application in accomplishing their work activities (Hartwick & Barki, 1994). This behavior is called post-adoptive behavior, which is the myriad feature-use behaviors and feature extension behaviors of individual users after an IT application has been made accessible to them (Jasperson, Carter, & Zmud, 2005). Among the commonly researched IT applications for its post-adoptive behavior is the knowledge management system (KMS) (Alavi & Leidner, 1999). The extremely challenging proposition faced by knowledge workers in contributing their knowledge to the KMS has led many organizations to auto-populate the content of their KMS. Even so, organizations still face challenges in persuading knowledge workers to retrieve knowledge from the KMS. After so much effort populating knowledge to the KMS, if the knowledge stored is not being retrieved and used in daily work activities, it is of no value.

Previous studies provide suggestions to organizations on how to motivate knowledge retrieval from the KMS. For instance, motivation may come through the bottom-up social influence across hierarchical levels (Wang, Meister, & Gray, 2013), by establishing collaborative norms in the organization (Bock, Kankanhalli, & Sharma, 2006), and by ranking the knowledge stored in the KMS (Sutanto & Jiang, 2013). The commonality of these studies is that they examined knowledge retrieval behavior in the context of a specific KMS provided by the focal organizations. Knowledge workers also store knowledge, such as information about customers, marketing research and plans, and knowledge about company products and services, by creating folders and files in local storage (e.g., local drives, thumb drives, etc.), and these local storages are accessed when particular knowledge is needed. When researching about knowledge retrieval, researchers should investigate not only the organization-created KMS but also the employees' self-created KMS.

In fact, there are two main components of a KMS: the system and the content. Considering system creation and content creation, we can distinguish three types of KMS: 1) the organization-created system with auto-populated knowledge content and/or knowledge stored by employees other than the target knowledge seekers; 2) the knowledge seekers' self-created systems and content; and 3) the organization-created system that contains knowledge stored by the knowledge seekers themselves. Most studies have examined knowledge retrieval from the first or third type of KMSs, and the impact of such KMS usage on work efficiency has not always been found to be positive (Ko & Dennis,

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2011). Having access to alternative KMS is important to identify those systems and holistically examine the impacts of knowledge retrieval activities on work efficiency from the different types of KMSs.

Building on uses and gratification theory (Rubin, 1985) and psychology of sunk cost (Arkes & Blumer, 1985), this study aims to holistically examine the extent of knowledge retrieval activities from the different types of KMSs and their impacts on knowledge seekers' work efficiency. According to uses and gratification theory, individuals continue using a medium because they derive process and content gratifications from using it. One of the important process gratifications from retrieving knowledge from a KMS is the simplicity in doing so (Watson & Hewett, 2006). Content gratification, on the other hand, concerns the satisfaction with the knowledge retrieved from the KMS (He, Fang, & Wei, 2009; Kankanhalli, Tan, & Wei, 2005). When the process of retrieving knowledge from a KMS is straightforward and the resultant knowledge search is satisfactory, knowledge workers should be motivated to continue seeking knowledge from that particular KMS. However, because the gratifications derived from a KMS are subjective, according to the psychology of sunk cost, there is a tendency to continue an endeavor once an investment in effort and time has been made (Arkes & Blumer, 1985). Therefore, although in reality, the process of retrieving knowledge from the self-created KMS may not be simple and the resultant knowledge search may not be satisfactory, the knowledge workers may perceive it as simple to use and as producing satisfactory results and thus continue retrieving knowledge from their self-created KMS in their daily work activities.

To achieve the study objective, which is to holistically examine the extent of knowledge retrieval activities from the different types of KMSs and their effects on the knowledge seekers' work efficiency, we collaborated with an IT call-center company. The company had implemented two KMSs, hereby referred to as KMSone and KMStwo. KMSone is embedded in the call-center's employees' daily work activities, such as the employee having to login into the system every day and insert customer complaints in the system's predefined fields. These inputs serve as knowledge contributions to KMSone. Hence, KMSone is an organization-created KMS that contains knowledge stored by the knowledge seekers themselves. In contrast, the knowledge stored in KMStwo is entered by the second-level support employees, who have received forwarded unsolved customer complaints from the call-center employees. The motivation behind the implementation of KMStwo is to provide the call-center employees access to more advanced knowledge to minimize the amount of call forwarding. Hence, KMStwo is an organization-created KMS that contains knowledge stored by employees other than the target knowledge seekers. In addition to these two types of organization-created KMSs, each call-center employee creates and maintains their own localized KMS in their local drives, hereby referred to as LocalKMS. These LocalKMSs, range from a Notepad file to sorted folders of Word-document files, are knowledge seekers' self-created KMSs and contents.

We surveyed 158 call-center employees and followed that with interviews and focus groups. The call-center company is a *unique setting* where the employees' work is time-critical, and their work efficiency is closely dependent on the sources they use to obtain the knowledge needed to answer customers' questions. Under that circumstance, the following questions were asked: Why do they retrieve knowledge from any of the KMSs available? Does knowledge retrieval from the respective KMS actually improve their work efficiency? The answers to these questions can reveal whether there is a personal bias with respect to the self-created KMS and/or self-created knowledge content that leads to continuous knowledge retrieval, even though the choice may not actually improve the employees' work efficiency.

We found that both the perceived process and content gratifications of a KMS affected the extent of knowledge retrieval activities from the respective KMS. Moreover, we found that only the degree of knowledge retrieval from KMSone led to higher work efficiency. We discovered that most of the time, the knowledge workers were searching and retrieving knowledge from KMSone and LocalKMS. They very rarely retrieved knowledge from KMStwo. Altogether, the findings from the survey which were corroborated with follow-up interviews and focus groups imply two things. First, the content and process gratifications in using an organization-created KMS that contains knowledge stored by employees other than the target knowledge seekers (i.e., KMStwo) are the lowest. Second, although the gratifications in using LocalKMS are higher than KMStwo, searching knowledge from LocalKMS was not always associated with improved work efficiency. Hence, we found evidence of psychological sunk cost in the continued use of a self-created system and content.

This paper is structured as follow. In the next section, we will summarize the extant literature on knowledge retrieval from KMS, identify the research gaps, and highlight how our study contributes to the identified gaps. Subsequently, we will explain the theoretical foundations of our study, i.e., uses and gratifications theory and psychology of sunk cost. This is followed by a presentation of our research model and research methodology. In the following sections, we will describe and discuss our findings and conclude the paper by highlighting how our study contributes to research and what the implications of our findings to practitioners.

2. Literature review

Knowledge retrieval is an important aspect of effective knowledge management (Alavi & Leidner, 2001). Prior studies have examined the determinants of retrieving knowledge from a KMS and provided suggestions to organizations on how to motivate knowledge retrieval from a KMS (Cerchione & Esposito, 2017).

Knowledge seekers' perceptions toward the characteristics of KMS affect their retrieval behavior. Perceived ease of use (Lai, 2009; Phang, Kankanhalli, & Sabherwal, 2009; Su & Contractor, 2011) and perceived usefulness (Chen, Hsieh, Van de Vliert, & Huang, 2015; Choi & Durcikova, 2014; Lai, 2009; He, Fang, & Wei, 2009) of KMS is positively related to the intention of knowledge use and retrieval. To be more specific, perceived searchability, actionability (Durcikova & Fadel, 2016), capability (Kankanhalli, Lee, & Lim, 2011), and usability (Phang et al., 2009) positively affect the knowledge retrieval behavior. The quality of the knowledge in a KMS is also essential: it has been found that perceived output quality (Durcikova & Gray, 2009; Kankanhalli et al., 2005), resource availability (Kankanhalli et al., 2011), expertise recognition of contributors (Su & Contractor, 2011), visibility, and result demonstrability (Hester, 2011) are positively related to knowledge retrieval. Thus, implementing rating-based knowledge rankings to recognize high quality knowledge could also positively influence knowledge retrieval (Sutanto & Jiang, 2013). However, even when the quality of knowledge content in a KMS can be assured, knowledge seekers' perceived task-technology fit also affects their retrieval behavior (Lin & Huang, 2009). In order to encourage knowledge retrieval from a KMS, the value of a KMS should be demonstrated (Wang, Meister, & Gray, 2011; Watson & Hewett, 2006), and knowledge seekers' satisfaction should be guaranteed (He, Fang, & Wei, 2009; Lai, 2009).

Knowledge seekers' characteristics also affect their retrieval behavior. Intrinsic motivation is positively related to knowledge retrieval (Kankanhalli et al., 2011). Knowledge seekers with strong learning orientations or facing intellectual demands will engage in knowledge retrieval (Gray & Durcikova, 2005; Gray & Meister, 2004). Their self-efficacy of KMS (Bock et al., 2006; Lin & Huang, 2008; Lin & Huang, 2009) and personal outcome expectations (Lin & Huang, 2008) also positively affect their knowledge retrieval. However, risk-averse knowledge seekers (Gray & Durcikova, 2005) and knowledge seekers who perceive image loss when seeking knowledge from others (Wang et al., 2011) will not actively engage in knowledge retrieval.

Social influence can also affect knowledge retrieval behavior (Su & Contractor, 2011). Knowledge-seeking intention is based on the

subjective norm of knowledge seeking, which is influenced by community identification (Lai, Chen, & Chang, 2014). In addition to the social pressure from the community or the company, knowledge seeking by peers and subordinates can also motivate knowledge retrieval, which suggests the positive effect of bottom-up social influence across hierarchical levels (Wang et al., 2013). Moreover, social relationships among KMS users are positively related to KMS usage (He, Qiao, & Wei, 2009). Establishing collaborative norms in the organization is beneficial for motivating knowledge retrieval (Bock et al., 2006).

Management and organizational supports can facilitate knowledge retrieval by incentivizing or rewarding KMS use, in general, and knowledge retrieval, in particular (Kankanhalli et al., 2005; Lai, 2009). Providing training and management support for users can also encourage knowledge retrieval from the KMS (Bock et al., 2006; He & Wei, 2009; Watson & Hewett, 2006). However, time and work pressures experienced by users have detrimental effects on their knowledge retrieval behavior (Gray & Durcikova, 2005).

Organizations encourage users to retrieve knowledge from KMSs because KMS use is positively related to work efficiency (González, Giachetti, & Ramirez, 2005; Kankanhalli et al., 2011; McCall, Arnold, & Sutton, 2008; Teo & Men, 2008). For instance, deep structure use of a KMS positively affects job performance of the users (Zhang, 2017). But the efficiency benefit could be temporary and could only be gained by experienced users (Ko & Dennis, 2011). Moreover, this relationship is contingent by several factors. For example, the benefit could be higher for nonroutine tasks, higher levels of absorptive capacity from the users, and higher levels of transformational leadership from organizations (Zhang, 2017). In addition, the benefit could be higher when task intensity is greater, and it could be lower when task environments demand rapidly changing information and knowledge (Kim, Mukhopadhyay, & Kraut, 2016).

Existing literature explored the determinants of knowledge retrieval and the effect of knowledge retrieval on users' performance separately, which prevents us from further observing the causes of different work performance obtained from using KMS. Moreover, prior studies have investigated users' knowledge retrieval behaviors from a particular KMS, but most of these studies focused on organization-created KMS. Users' knowledge retrieval behavior and related performance benefits could be affected when they can access alternative knowledge sources (Kim et al., 2016). In accessing knowledge content from an organization-created KMS, knowledge workers can also access the knowledge content from folders and files created in their local storages. This study distinguishes three types of KMSs based on who creates the system and populates the content: 1) an organization-created system with auto-populated knowledge content and/or knowledge stored by employees other than the target knowledge seekers; 2) a knowledge seekers' self-created system and content; and 3) an organization-created system that contains knowledge stored by the knowledge seekers themselves. Building on uses and gratifications theory and psychology of sunk cost, we holistically examine knowledge workers' perceptions of these systems and their respective content, their extent of knowledge retrieval behaviors from each system, and the effect on their work efficiency. In the following section, we explain the theoretical foundations of the study.

3. Theoretical foundations

3.1. Uses and gratifications theory

Uses and gratifications theory (UGT) originates from researches in traditional mass media communication contexts, such as radio and television (McGuire, 1974; Rubin, 1985). In these contexts, it is used to understand consumers' motivations and concerns in order to explain why they become involved in particular types of media and what gratifications they receive from that involvement (Ku, Chen, & Zhang, 2013; Ruggiero, 2000). In past decades, UGT has been used to examine the use of new forms of media and applications in the Internet context, such as online websites (Ebersole, 2000), social networking services (Cheung, Chiu, & Lee, 2011), mobile applications (Sutanto, Palme, Tan, & Phang, 2013), online games (Wu, Wang, & Tsai, 2010), and virtual communities (Sangwan, 2005).

UGT posits that users use a medium either for the experience of the process itself, which is categorized as process gratification (Cutler & Danowski, 1980), or for the content it conveys, which is categorized as content gratification (Stafford & Stafford, 1996). The distinctions between process and content gratifications should be defined in context with operational definitions and resulting measures that are specific to the medium (Stafford, Stafford, & Schkade, 2004). For example, aimless surfing on websites is an Internet characterization of process gratification, whereas bookmarking a site might be more representative of motivations arising from content gratifications (Stafford & Stafford, 2001). Thus, process gratification has been measured by the frequency of logging into a system (Venkatesh, Speier, & Morris, 2003) or the frequency of launching the application (Sutanto et al., 2013), and content gratification has been measured by the frequency of saving the application's contents (Sutanto et al., 2013) or the frequency of bookmarking the sites (Stafford & Stafford, 2001).

Relating to our context of KMSs, knowledge workers may enjoy the process of knowledge retrieval from the KMS or the quality of retrieved knowledge. The gratifications derived could motivate them to continuously retrieve knowledge from the KMS. However, it is important to note that such gratifications are perception based and could be biased because of sunk cost.

3.2. Psychology of sunk cost

Sunk cost refers to a psychological commitment that may influence an individual's intention to continue a current action, even if it is contrary to rational cost benefit analysis (Samuelson & Zeckhauser, 1988). Since the individual desires to justify previous commitments to an action, the psychology of sunk cost motivates a status quo bias, which can explain user behavior of adoption and resistance toward the systems (Kim & Kankanhalli, 2009; Samuelson & Zeckhauser, 1988). Sunk cost affects an individual's acceptance of the new information systems because it is a part of switching costs, which reduce the value of a new information system (Kim & Kankanhalli, 2009). When individuals adopt new information systems, they may perceive higher levels of sunk costs compared with the incrementally improved versions of the current information systems (Lee & Joshi, 2017). The psychological commitment derived from sunk costs may prompt them to resist an information system (Polites & Karahanna, 2012).

Sunk cost has been measured as the amount of time and effort to learn to use the current information systems, which influences perceived ease of use and relative advantage. Thus, users' learning efforts, experience, and expertise in the current information systems would represent sunk costs of adopting new information systems (Polites & Karahanna, 2012). Although the role of sunk cost in studying user behavior toward the systems has been identified, only a few studies have empirically examined or even addressed sunk costs (Lee & Joshi, 2017). For instance, the perceived effort and time required affects the adoption of online social network services (Hu, Poston, & Kettinger, 2011), and even after the adoption of these services, usage intention can be lowered due to high switching-stress creators formed by sunk costs (Maier, Laumer, Weinert, & Weitzel, 2015). Another study also found user's intention to switch from traditional IT services to cloud computing services was negatively influenced by the expected switching costs, whose antecedents are satisfaction with the traditional IT services, even when in reality, it was more beneficial to switch to cloud computing services (Park & Ryoo, 2013).

4. Hypotheses development

Our thesis is as follow:

The perceived search simplicity and content quality of a KMS affect knowledge workers' retrieval behavior, which leads to higher work efficiency when their perceptions toward a KMS is not biased by their previous time and effort investments.

According to UGT, knowledge workers may retrieve knowledge from a particular KMS for the experience of the process itself (Cutler & Danowski, 1980). These users could receive gratification mainly from the process of retrieving the knowledge (Cutler & Danowski, 1980), which indicates that a psychological need is gratified by the system usage process rather than from the knowledge stored in the KMS (Chen, 2011). Process gratification has been studied in the Internet context. For example, active Twitter users gratify the need to connect with others on Twitter (Chen, 2011) and use Twitter for fun (Liu, Cheung, & Lee, 2010), which lead to their satisfaction and use of Twitter (Liu, Cheung, & Lee, 2016). In another example, users are gratified by the personalization feature in a mobile application, which leads to active usage of the application (Sutanto et al., 2013).

Since process gratification concerns the actual use of the medium itself (Cutler & Danowski, 1980), several dimensions related with process gratifications have been identified in the Internet context, such as searching and surfing (Stafford et al., 2004). Among these dimensions, searching is the most important indicator for process gratification (Stafford et al., 2004). In other studies, ease of use has been identified as one important dimension for browsing commercial websites (Eighmey, 1997). In the context of KMSs, knowledge searching is the core process for knowledge retrieval. When searching for the relevant knowledge in a KMS, knowledge workers may enjoy the simplicity of the searching process, and this process gratification may increase their active usage of KMS. Accordingly, we hypothesize:

H1. Perceived search simplicity increases the extent of knowledge retrieval from a KMS.

In KMS, perceived knowledge quality also affects knowledge retrieval behavior (Durcikova & Gray, 2009; Kankanhalli et al., 2005). Based on UGT, content gratification is the purposeful use of a medium (Stafford et al., 2004). Several dimensions related with content gratifications have been identified in the Internet context, such as learning, knowledge, and information (Stafford et al., 2004). Users may be gratified by the content carried by a medium and become involved in that medium. For example, content gratification of Twitter resides in the information content carried through Twitter, which affects users' satisfaction and continuous use of Twitter (Liu et al., 2016). In the context of KMSs, the gratification of the content quality in KMS may lead knowledge workers into actively retrieving knowledge from the KMS. Thus, we hypothesize:

H2. Perceived content quality increases the extent of knowledge retrieval from a KMS.

KMS knowledge retrieval has been found to positively affect knowledge workers' work efficiency (Kankanhalli et al., 2011; McCall et al., 2008; Teo & Men, 2008). However, the degree of knowledge retrieval from a KMS may not lead to better efficiency due to a knowledge worker's biased perceptions toward the KMS. According to the psychology of sunk cost, knowledge workers could be committed to their self-created system and content because of their previous efforts and time investment in it, which in turn bias their perceptions of the simplicity of retrieving knowledge from the self-created KMS and the satisfaction of the knowledge retrieved from their self-created content. Consequently, the extent of knowledge retrieval from a self-created KMS may be less impactful on their work efficiency compared to the extent of knowledge retrieval from an organization-created KMS. Therefore, we hypothesize:

H3. Compared with a self-created KMS, the extent of knowledge retrieval from an organization-created KMS has greater impacts on knowledge worker's efficiency.

5. Research methodology

5.1. Research site

To test the hypotheses, we collaborated with the customer service department of a large technology provider. The customer service department under study provides support for customers' technical problems. It is common for the customer service department to cover countless technology-related products and services, such as software, hardware, or network-related issues. Given that the complexity of IT infrastructures has significantly increased in the last years, customers may encounter a wider range of technical problems that require increasingly complex solutions. Consequently, customers may often need to wait considerably longer or even contact customer service specialists several times before their enquiries are adequately addressed. The customer service department under study faces two important challenges in responding to customers' enquiries. First, the customer service department is the customer's first contact point for support, and customers expect instant answers to their questions from its workers. Second, an important goal for the customer service department is to reduce call-handling duration via continuous tracking and efficiency assessment, and it is required to develop mechanisms that enable customer service specialists to solve the overwhelming customer enquiries.

The organization created and implemented two KMSs, namely KMSone (see Fig. 1) and KMStwo (see Fig. 2). These KMSs are deeply embedded in the customer service department's daily work. When responding to customer enquiries, the customer service specialists will normally attempt to find the answers to the enquiries using KMSone. If, in terms of actionable knowledge, answers cannot to be found in KMSone, the customer service specialists can alternatively gain in-depth knowledge with the help of KMStwo. Although these two systems were designed to complement each other in the customer service practice, it appears that the customer service specialists have repeatedly encountered difficulties in applying relevant knowledge from these two systems when dealing with customer enquiries. In this sense, a significant proportion of customer specialists have been employing custom methods to help them compensate for the shortcomings of these KMSs. They have created and maintained their own localized KMS, such as a Notepad file or sorted folders of Word-document files, on their hard drives and use self-created Java-based search tools to search for the knowledge.

5.2. Data collection

We collected two rounds of data (i.e., a survey and interviews/focus groups). Findings from the interviews/focus groups are also triangulated to add richness to the survey's findings.

The main variables for the survey are knowledge search simplicity, quality of the retrieved knowledge, extent of knowledge retrieval, and work efficiency. Regarding the control variables, we considered the factors that have been previously shown in the literature to affect knowledge retrieval and work efficiency. We included the demographic variables of survey respondents, such as gender, age, experience in the current position, and experience in the current area, as well as the variables characterizing the work environment, such as job stress level, training received, sourcing from colleagues, and task analyzability (Kim et al., 2016).

Two main variables, i.e., knowledge search simplicity and work efficiency, have a single measure. The weakness of single item measures is the inability to validate whether the variable is accurately captured; however, in some situations, single item measure is the most

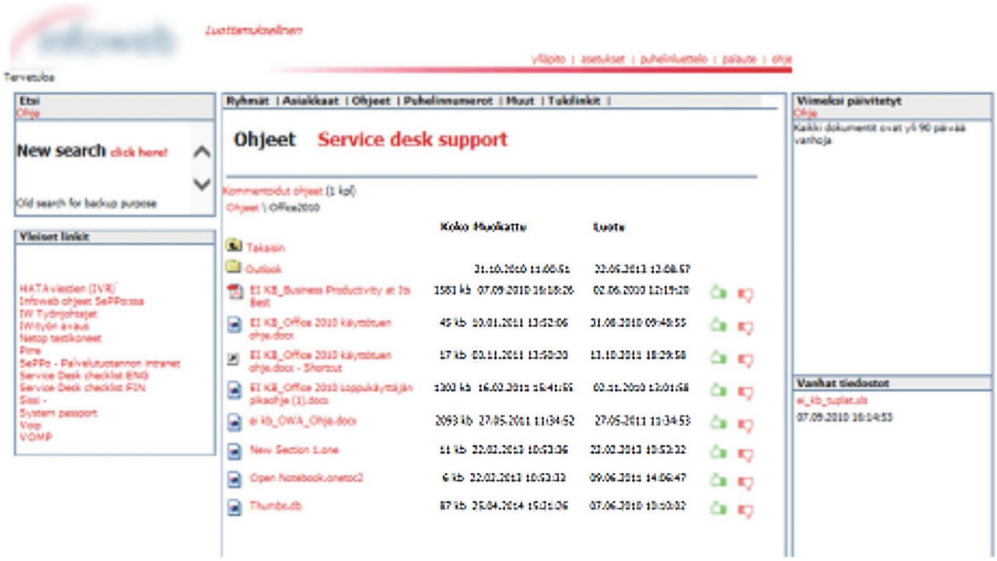

Fig. 1. Screenshot of KMSone (blurred for anonymity).

appropriate (Straub, Boudreau, & Gefen, 2004). For example, in their MISQ paper, Siponen and Vance (2010) utilized some single item measures. The collaborating organization required us to minimize the number of survey questions. Before conducting the survey, we assessed the conceptual validity of the items by adopting Moore and Benbasat's procedure (Moore & Benbasat, 1991). The conceptual validation was carried out using structured sorting (with variable category labels). The goal was to gain a clear indication that the survey items are indeed measuring what they are supposed to measure. A set of five judges (researchers with substantial experience in the fields of information systems and knowledge management) were asked to sort the items. Based on the sorting results, we revised the scales and conducted another round of sorting to confirm the construct validity. Following this positive result, we distributed the survey to the customer service specialists. The customer support specialists have clear time targets that need to be achieved, and they need to efficiently address questions from customers. On a daily basis, they receive up-to-date summaries of their efficiency of the previous day and the whole week. Thus, we cross-checked their responses with summaries of their work efficiency to ensured that the self-reported work efficiency reflected their actual work efficiency. Unfortunately, we could not use the objective efficiency data in our study because the company prevented us from "exporting" the data outside of the company premises. An overview of the survey items is presented in Table 1. Six-point Likert scales from strongly disagree to strongly agree (never to very frequently for the knowledge retrieval variable) was used. A total of 158 survey responses

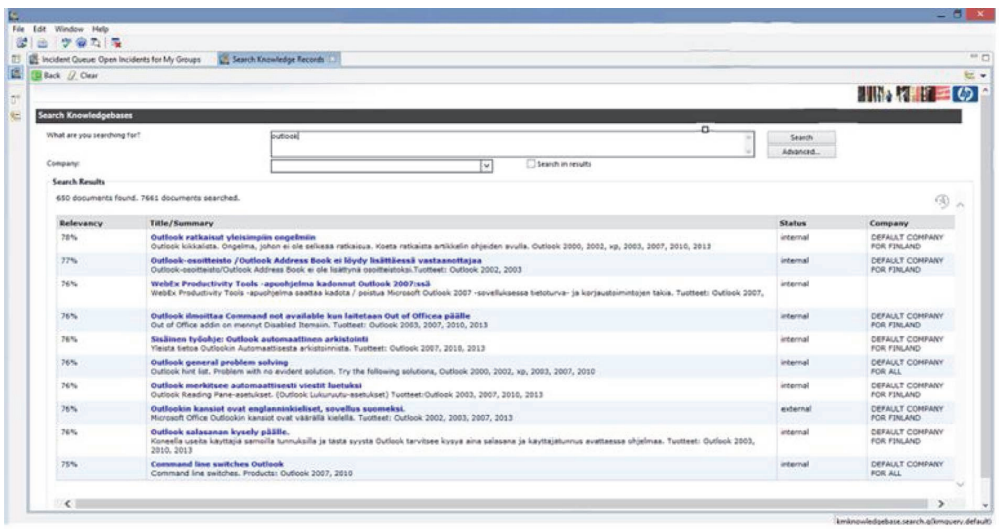

Fig. 2. Screenshot of KMStwo (blurred for anonymity).

Table 1
Survey Items.

Construct	Reference	Items	Mean (S.D.)/ Frequency
Search Simplicity (SS_KMSone)	Phang et al. (2009)	1: Searching for content in KMSone is simple.	4.487 (1.173)
Search Simplicity (SS_KMStwo)		1: Searching for content in KMStwo is simple.	2.557 (1.265)
Search Simplicity (SS_LocalKMS)		1: Searching for content in LocalKMS is simple.	4.158 (1.280)
Knowledge Quality (KQ_KMSone)	Durcikova and Gray (2009)	1: The content in KMSone meets my needs;	4.114 (1.136)
		2: I am satisfied with the content in KMSone;	3.943 (1.254)
		3: The overall quality of content in KMSone is high.	3.892 (1.215)
Knowledge Quality (KQ_KMStwo)		1: The content in KMStwo meets my needs;	3.025 (1.248)
		2: I am satisfied with the content in KMStwo;	3.019 (1.275)
		3: The overall quality of content in KMStwo is high.	3.070 (1.317)
Knowledge Quality (KQ_LocalKM)		1: The content in LocalKMS meets my needs;	4.070 (1.228)
		2: I am satisfied with the content in LocalKMS;	3.880 (1.208)
		3: The overall quality of content in LocalKMS is high.	3.804 (1.250)
Knowledge Retrieval (KR_KMSone)	Phang et al. (2009)	1: To what extent do you use knowledge from KMSone when solving a customer case?	4.728 (1.017)
		2: When working on a customer case, to what extent do you look in KMSone to find solutions to similar cases?	4.709 (1.039)
Knowledge Retrieval (KR_KMStwo)		1: To what extent do you use knowledge from KMStwo when solving a customer case?	2.285 (1.191)
		2: When working on a customer case, to what extent do you look in KMStwo to find solutions to similar cases?	2.329 (1.290)
Knowledge Retrieval (KR_LocalKMS)		1: To what extent do you use knowledge from LocalKMS when solving a customer case?	4.127 (1.330)
		2: When working on a customer case, to what extent do you look in LocalKMS to find solutions to similar cases?	4.120 (1.398)
Sourcing from Colleague (SC)	Gray and Durcikova (2005)	1: To what extent do you discuss problems with colleagues when you need to improve your knowledge on a topic or issue related to work?	4.943 (0.936)
		2: When you work on a challenging case, to what extent do you communicate with your colleagues who may have encountered similar issues?	5.120 (0.790)
Task Analyzability (TA)	Nidumolu (1995)	1: To what extent is there a clearly known way to solve a customer case?	4.519 (0.832)
		2: To what extent are there precise instructions that can be followed when solving customer cases?	4.259 (0.887)
		3: To what extent are there common practices to work on customer cases?	4.342 (0.891)
Job Stress (JS)	Shigemi, Mino, Ohtsu, and Tsuda (2000)	1: To what extent is there too much trouble at work?	3.930 (1.038)
		2: To what extent is there too much work to handle?	4.234 (0.982)
		3: To what extent is there pressure on subordinate employees?	4.342 (0.953)
Training (TR)	Chen and Huang (2009)	1: To what extent are training activities available for new employees?	3.949 (1.036)
		2: To what extent do training programs exist?	3.766 (0.922)
Efficiency (EF)	Henderson and Lee (1992)	1: To what extent are you able to operate efficiently when solving customer cases? (**Note**: we cross-checked the responses with summaries of their efficiency on the previous day and previous week; we found that their responses were consistent with their actual work efficiency.)	4.759 (0.783)
Age		21 and under	2
		22–34	100
		35–44	38
		45–54	13
		55–64	5
		65 and above	0
Gender		Female	56
		Male	102
Experience Current Position		How long have you been employed in the current position?	
		< 4 months	15
		4 months–1 year	32
		1–2 years	27
		2–5 years	44
		5–10 years	32
		> 10 years	8
Experience Current Area		How long have you been working in customer service?	
		< 4 months	8
		4 months–1 year	18
		1–2 years	16
		2–5 years	44
		5–10 years	54
		> 10 years	18

(102 male and 56 female) were returned. The descriptive characteristics of the respondents are also shown in Table 1.

To gain a better understanding of knowledge workers' (perception-based) gratifications toward the organization-created KMS, interviews and focus groups with a total of 45 customer service specialists were conducted. During the interviews, we specifically asked about the functionalities and the usage behavior of the KMS. A comprehensive understanding of knowledge retrieval practices in the customer service department was obtained from the interviews, which adds richness to the findings.

6. Findings

Based on the descriptive statistics of the survey items shown in Table 1, it seems that the respondents' perceived knowledge quality and search simplicity of KMStwo (organization-created system and populated content) are much lower compared to KMSone (organization-created system, customer service specialists-created content) and LocalKMS (customer service specialists-created system and content). Moreover, it seems that they retrieved knowledge more frequently from KMSone and LocalKMS. Partial least squares (PLS) modeling technique

Table 2
Loadings, Reliability, and Validity of Constructs for KMSone.

Construct	Items	Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted	KQ	KR	SC	TA	JS	TR	EF	SS
KQ	1	0.940	0.941	0.962	0.895	**0.946**							
	2	0.961											
	3	0.936											
KR	1	0.949	0.889	0.947	0.900	0.573	**0.949**						
	2	0.948											
SC	1	0.915	0.801	0.909	0.834	0.136	0.248	**0.913**					
	2	0.911											
TA	1	0.896	0.845	0.906	0.762	0.572	0.445	0.216	**0.873**				
	2	0.882											
	3	0.839											
JS	1	0.875	0.748	0.853	0.659	−0.210	−0.173	−0.115	−0.206	**0.812**			
	2	0.765											
	3	0.792											
TR	1	0.949	0.882	0.944	0.895	0.375	0.268	0.087	0.299	−0.323	**0.946**		
	2	0.942											
EF	1	1	1	1	1	0.428	0.516	0.132	0.566	−0.206	0.240	**1**	
SS	1	1	1	1	1	0.507	0.474	0.215	0.274	−0.175	0.266	0.424	**1**

Table 3
Loadings, Reliability, and Validity of Constructs for KMStwo.

Construct	Items	Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted	KQ	KR	SC	TA	JS	TR	EF	SS
KQ	1	0.976	0.973	0.982	0.949	**0.974**							
	2	0.982											
	3	0.964											
KR	1	0.950	0.901	0.953	0.910	0.475	**0.954**						
	2	0.958											
SC	1	0.929	0.801	0.909	0.833	0.028	−0.104	**0.913**					
	2	0.896											
TA	1	0.897	0.845	0.906	0.762	0.254	0.040	0.214	**0.873**				
	2	0.880											
	3	0.840											
JS	1	0.819	0.748	0.850	0.654	−0.176	−0.270	−0.092	−0.194	**0.809**			
	2	0.729											
	3	0.872											
TR	1	0.963	0.882	0.943	0.892	0.273	0.139	0.084	0.297	−0.339	**0.944**		
	2	0.926											
EF	1	1	1	1	1	0.128	0.035	0.130	0.567	−0.208	0.244	**1**	
SS	1	1	1	1	1	0.435	0.562	0.055	0.013	−0.214	0.089	0.027	**1**

Table 4
Loadings, Reliability, and Validity of Constructs for LocalKMS.

Construct	Items	Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted	KQ	KR	SC	TA	JS	TR	EF	SS
KQ	1	0.929	0.946	0.965	0.903	**0.950**							
	2	0.969											
	3	0.952											
KR	1	0.941	0.867	0.937	0.882	0.560	**0.939**						
	2	0.937											
SC	1	0.878	0.801	0.907	0.830	0.254	0.212	**0.911**					
	2	0.943											
TA	1	0.896	0.845	0.906	0.762	0.376	0.076	0.222	**0.873**				
	2	0.880											
	3	0.842											
JS	1	0.851	0.748	0.853	0.659	−0.098	−0.053	−0.110	−0.201	**0.812**			
	2	0.749											
	3	0.832											
TR	1	0.960	0.882	0.943	0.893	0.273	0.108	0.094	0.297	−0.332	**0.945**		
	2	0.929											
EF	1	1	1	1	1	0.381	0.216	0.135	0.566	−0.208	0.243	**1**	
SS	1	1	1	1	1	0.576	0.578	0.181	0.270	−0.182	0.169	0.316	**1**

and SmartPLS v.3 were used for our data analysis. The item loadings and the results of reliabilities and validities are shown in Table 2 (KMSone), Table 3 (KMStwo), and Table 4 (LocalKMS). The values of Cronbach's alpha and composite reliability, which are greater than 0.70, and the values of Average Variance Extracted (AVE), which are greater than 0.50, indicate the satisfactory reliability and convergent validity for all these constructs. The discriminant validity is also satisfactory, as the square roots of the AVE are greater than any of the inter-construct correlations. Given the satisfactory measurement model, our hypotheses could then be tested by examining the structural model.

As shown in Table 5, all values of Variance Inflation Factor (VIF) are smaller than 5; this reduces the concern of multi-collinearity among

Table 5
Collinearity Check.

Construct	KMSone		KMStwo		LocalKMS	
	Knowledge Retrieval	Efficiency	Knowledge Retrieval	Efficiency	Knowledge Retrieval	Efficiency
Knowledge Quality_KMSone	1.995	2.197				
Knowledge Quality_KMStwo			1.453	1.636		
Knowledge Quality_LocalKMS					1.737	1.987
Search Simplicity_KMSone	1.452	1.530				
Search Simplicity_KMStwo			1.360	1.627		
Search Simplicity_LocalKMS					1.550	1.839
Knowledge Retrieval		1.733		1.817		1.855
Sourcing from Colleague	1.141	1.164	1.104	1.154	1.157	1.172
Job Stress	1.218	1.219	1.247	1.288	1.232	1.235
Task Analyzability	1.567	1.608	1.229	1.233	1.305	1.362
Training	1.293	1.294	1.257	1.257	1.235	1.235
Age	1.462	1.473	1.429	1.431	1.453	1.466
Gender	1.155	1.159	1.174	1.212	1.177	1182
Experience_area	1.855	1.868	1.891	1.912	1.872	1.875
Experience_position	1.909	1.924	1.911	1.915	1.899	1.930

Table 6
Survey Results for KMSone.

	Knowledge Retrieval	Efficiency		
	Path coefficients	*Path coefficients*	*Indirect effect*	*Total effect*
Knowledge Quality	**0.341*****	−0.117	**0.103****	−0.014
Search Simplicity	**0.212****	**0.227****	**0.064***	**0.291*****
Knowledge Retrieval		**0.303*****		
Control Variables				
Sourcing from Colleague	0.113	−0.051	0.034	−0.016
Job Stress	−0.018	−0.067	−0.006	−0.073
Task Analyzability	0.154	**0.443*****	0.047	**0.489*****
Training	0.024	−0.003	0.007	0.004
Age	0.080	−0.009	0.024	0.015
Gender	−0.044	**0.143***	−0.013	0.130
Experience_area	0.087	−0.118	0.026	−0.091
Experience_position	−0.094	0.156	−0.028	0.127
R square	0.423	0.478		

Note: Significant relationships are in bold.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 7
Survey Results for KMStwo.

	Knowledge Retrieval	Efficiency		
	Path coefficients	*Path coefficients*	*Indirect effect*	*Total effect*
Knowledge Quality	**0.317*****	−0.061	0.003	−0.058
Search Simplicity	**0.383*****	0.032	0.003	0.035
Knowledge Retrieval		0.008		
Control Variables				
Sourcing from Colleague	**−0.167***	0.032	−0.001	0.031
Job Stress	**−0.150***	−0.103	−0.001	−0.104
Task Analyzability	−0.044	**0.542*****	0.000	**0.541*****
Training	0.004	0.069	0.000	0.069
Age	0.034	0.061	0.000	0.062
Gender	−0.144	**0.135***	−0.001	**0.134***
Experience_area	−0.107	−0.086	−0.001	−0.087
Experience_position	0.046	0.146	0.000	0.146
R square	0.450	0.362		

Note: Significant relationships are in bold.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

predictors. Tables 6–8 show the results of the analysis. Concerning KMSone (Table 6), we find that knowledge quality (coefficient = 0.341, $p < 0.001$) and search simplicity (coefficient = 0.212, $p < 0.001$) positively affect knowledge retrieval, which subsequently leads to higher work efficiency (coefficient = 0.303, $p < 0.001$). For the other two KMS, knowledge quality (coefficient = 0.317, $p < 0.001$; coefficient = 0.367, $p < 0.001$) and search simplicity (coefficient = 0.383, $p < 0.001$; coefficient = 0.394, $p < 0.001$) also positively affect knowledge retrieval. Thus, H1 and H2 are supported. However, knowledge retrieval in KMStwo (coefficient = 0.008, $p > 0.05$) or LocalKMS (coefficient = 0.094, $p > 0.05$) does not lead to higher efficiency. Thus, H3 is partially supported.

Regarding the control variables, task analyzability positively affects knowledge workers' efficiency (coefficient = 0.489, 0.541, and 0.462, respectively, $p < 0.001$), which is expected because less-complex customer enquiries should lead to better work efficiency. Moreover, task analyzability negatively affects knowledge retrieval only for LocalKMS (coefficient = −0.175, $p < 0.05$). Interpreting this finding together with the finding that knowledge retrieval from LocalKMS has no effect on work efficiency means that there is a serious issue of a positive bias toward the LocalKMS.

A combined structural equation modeling that contains the degree of knowledge retrievals from the three types of KMS is shown in Fig. 3. The results are consistent: compared with a self-created KMS (LocalKMS), the extent of knowledge retrieval from organization-created KMS (KMSone) has a significantly greater impact on knowledge worker's efficiency; but, this is not the case for organization-created KMS whose content is not populated by the knowledge workers themselves (KMStwo).

The interviews and focus groups indicated a vastly unexploited potential of search functionalities in both KMSone and KMStwo. On the one hand, a search in KMStwo appears to be difficult to use and is by far not exploited at its full potential: the customer service specialists are not fully aware of how to refine search results and thus prefer to avoid using KMStwo for solving customer cases. On the other hand, KMSone does not offer suitable support for refining the output of the search, but it does appear to contain more comprehensive applicable knowledge than KMStwo. The interviews further revealed that KMStwo contains too much content, which prevents the time-pressured customer service specialists from using it, and thus they look for knowledge from alternative resources. In addition to using KMSone, the customer service specialists prefer to use their own LocalKMS. A summary of all the issues identified following our interviews is presented in Table 9.

The insights from the interviews and focus groups provide us some

Table 8
Survey Results for LocalKMS.

	Knowledge Retrieval	Efficiency		
	Path coefficients	*Path coefficients*	*Indirect effect*	*Total effect*
Knowledge Quality	**0.367*****	0.104	0.035	0.139
Search Simplicity	**0.394*****	0.059	0.037	0.096
Knowledge Retrieval		0.094		
Control Variables				
Sourcing from Colleague	0.091	−0.011	0.009	−0.003
Job Stress	0.041	−0.106	0.004	−0.102
Task Analyzability	**−0.175***	**0.479*****	−0.017	**0.462*****
Training	0.000	0.035	0.000	0.035
Age	0.083	0.024	0.008	0.032
Gender	0.050	0.099	0.005	0.104
Experience_area	0.039	−0.068	0.004	−0.064
Experience_position	−0.129	0.174	−0.012	0.161
R square	0.461	0.396		

Note: Significant relationships are in bold.
$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.

possible explanations for the findings from the survey. Most of the customer service specialists are grateful for the opportunity to use the LocalKMS to a great extent. Two of them mentioned that:

> *We have the most [frequent problems described] there. […]. And it's it takes about minute or two to find all the needed information from this guide. […] the simplest way, and the fastest way is to use this guide, where we can find all the information.*

> *We have also made for ourselves like a guide, where you can find all the [customer specific] information.*

The perceived ease of use and relative advantage of the LocalKMS are probably induced by the amount of time and effort to create and use it. A customer service specialist mentioned:

> *We don't often use [KMSone] and we have our own network drive and all the instructions are there …we have about 90 customers and …have all the instructions there…most of them are word documents….*

It appears from the interviews and focus groups that the sunk costs of creating LocalKMS increases the switching cost to use organization-created KMS (Polites & Karahanna, 2012) when handling customers' inquires. The customer service specialists also emphasized that search simplicity is the most prevalent system feature, which is probably because of their work time constraints. The customer support specialists have clear time targets that need to be achieved, and they need to efficiently address questions from customers. They are constantly under time pressures, and the daily summaries of their work efficiency make it worse as the summaries even rank their work efficiency compared to others.

6.1. Additional findings

Based on the interviews and focus groups' insights, we did another test to check whether the extent of knowledge retrieval from LocalKMS negatively moderates the effect of knowledge retrieval from KMSone on work efficiency. We found that it does have a negative moderating effect on knowledge retrieval from KMSone (see Fig. 4). Because only knowledge retrieval from KMSone positively improves work efficiency and there is a vastly unexploited potential of search functionalities in KMSone, this additional finding heightens the concern of a positive bias on self-created KMS.

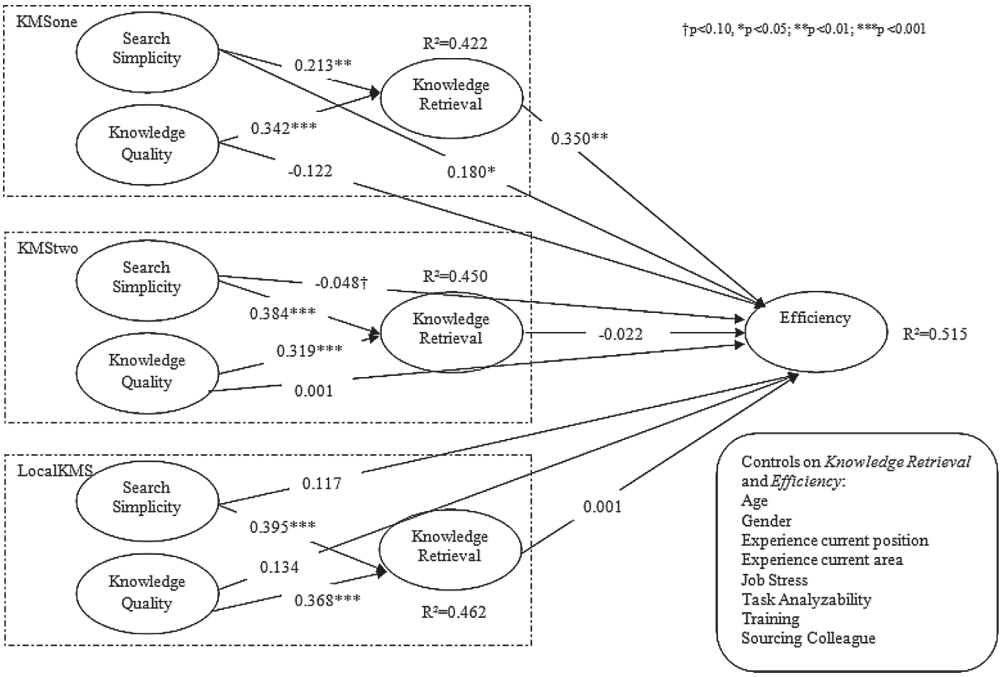

Fig. 3. Combined Model.

Table 9
Summary of interview insights.

Aspects	Summary of findings	Interview quotations
Knowledge Retrieval from KMSone	The search engine in KMSone is very sensitive to the keywords that are typed in The search in KMSone is not fast enough	"In KMSone if I use the wrong word I might get no answers […] one word makes a difference. …" "I think [that the search in KMSone] could be faster. […] it would be easier if it would be like a Wiki, Wikipedia type of solutions or something like that and the searches would be fast"
Knowledge Retrieval from KMStwo	The search in KMStwo provides many irrelevant answers	"The organization [in KMStwo] is so bad […]. In KMStwo I might have like a thousand answers. And then I start clicking. And at the same time I have a customer waiting for an answer …"; "It's like you [type in a query] and you search … and the KMStwo offers you … any possible kind of answer"
Knowledge Retrieval from LocalKMS	Development of customer-enquires' guides, as alternative to KMSone and KMStwo	"[…] we have also made for ourselves like a guide, where you can find all the [customer specific] information. And if the information is not there, and we find an answer to that question, we just add it in that guide." "Sometimes we use the guide that we have. We have the most [frequent problems described] there. […]. And it takes about minute or two to find all the needed information from this guide. […] the simplest way, and the fastest way is to use this guide, where we can find all the information." "We have created Excel files where there are certain problems or programs [described]. What to do in case of if the password is locked… So we can first look at the Excel file"

7. Discussions and implications

This study aims to examine knowledge worker's retrieval behavior in three types of KMSs: 1) an organization-created system and content, 2) an organization-created system whose content is inputted by the knowledge workers themselves, and 3) a self-created system and content. The study also aims to examine whether frequent knowledge retrieval from these different types of KMSs leads to higher work efficiency. The call-center company that we collaborated with for this research is a *unique setting* in which the employees' work is time critical and their work efficiency closely depends on the way they source the knowledge needed to answer customers' questions.

According to UGT, users' process and content gratifications lead to more frequent knowledge retrieval from a KMS, which subsequently leads to higher work efficiency (Kankanhalli et al., 2011). However, according to the psychology of sunk cost, users may continue retrieving knowledge from self-created KMS because of positive bias in their perceived gratifications. Thus, knowledge retrieval from self-created KMS does not necessarily translate into work efficiency. We found that both perceived process gratification (reflected by search simplicity) and content gratification (reflected by content quality) with the KMS led to more frequent knowledge retrieval from the respective KMS. Moreover, although frequent knowledge retrieval from KMSone (an organization-created system whose content is inputted by the knowledge workers themselves) led to higher work efficiency, knowledge retrieval from KMStwo (an organization-created system and content) or LocalKMS (a

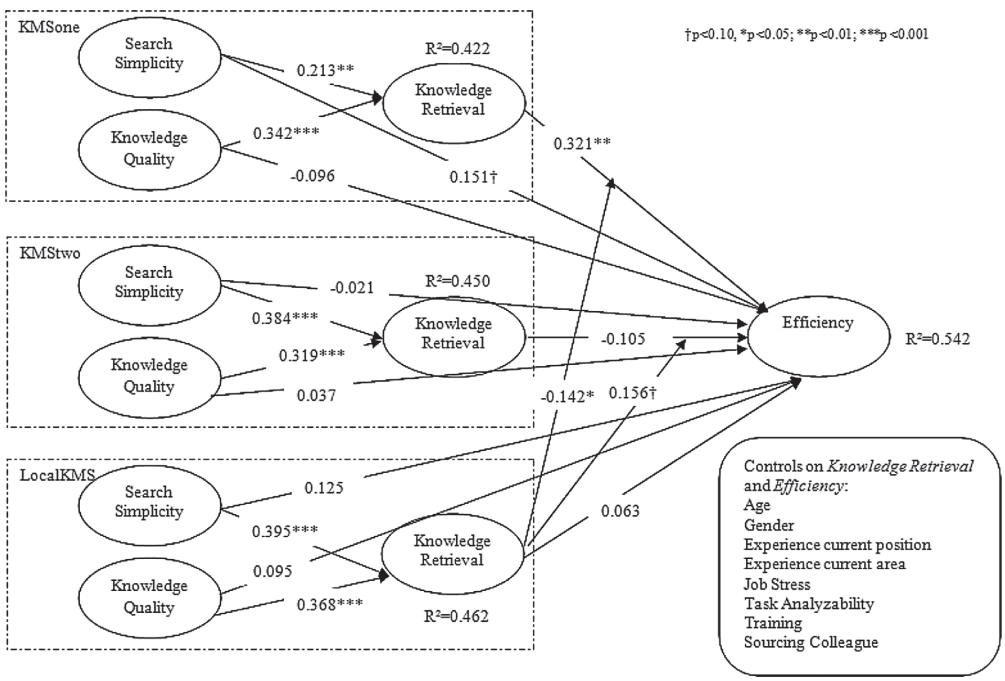

Fig. 4. Moderating Effect of LocalKMS.

self-created system and content) had negligible impact on knowledge workers' work efficiency. Concerning KMStwo, knowledge workers had relatively low content and process gratifications, which discouraged them from retrieving knowledge from KMStwo. For the LocalKMS, knowledge workers perceived high process and content gratifications, which encouraged them to retrieve knowledge from it frequently. However, their work efficiency was not highly improved along with the frequent knowledge retrieval from the LocalKMS. Evidently, their psychological commitments toward the LocalKMS, due to their previous investment in effort and time, induced them to continue using the LocalKMS (Kim & Kankanhalli, 2009; Samuelson & Zeckhauser, 1988), although, in reality, retrieving knowledge from the LocalKMS did not significantly improve their work efficiency. Moreover, we found that the frequent use of the LocalKMS due to the knowledge workers' positive bias negatively moderated the effect of their use of KMSone on their work efficiency.

Although surveys and interviews allowed us to obtain an in-depth understanding of the effects of multiple KMSs on customer service specialists' work efficiency, and we cross-checked their responses against objective reports when we were onsite, we could not export these objective data for analytic purpose due to confidentiality issues. Hence, findings of this study should be viewed in light of the limitation of the study. Nevertheless, this study offers several contributions to research and practice.

7.1. Contributions to research

This study contributes to post-adoption literature of information systems by examining organization-created KMS in conjunction with knowledge workers' self-made local KMS. Users' knowledge retrieval behavior from an organization-created KMS and related work efficiency are affected by alternative accessible knowledge sources users, such as colleagues, physical knowledge sources, or data warehouses (Kim et al., 2016). However, these alternative sources have significant differences compared with organization-created KMSs. For instance, knowledge in physical sources cannot be searched automatically via keywords, and data warehouses contain too much irrelevant content compared with specific KMSs. Through managing local folders, knowledge workers can maintain specific knowledge and accordingly customize the search function. Regardless of the strengths and weaknesses of the "other KMSs," these available alternatives, especially the self-developed alternatives, may discount the use of an organization-created KMS.

This study also contributes to the knowledge management literature in several ways. Knowledge retrieval from KMSs has been found to positively affect users' work efficiency (Kankanhalli et al., 2011; McCall et al., 2008). But the level of performance benefit depends on other factors, such as user experience (Ko & Dennis, 2011) and task characteristics (Kim et al., 2016). More importantly, the capability of a KMS is decisive on whether users' work efficiency could be improved through frequent knowledge retrieval (Kankanhalli et al., 2011). However, the existing knowledge management literature has mainly focused on perceived output quality of KMSs (Durcikova & Gray, 2009; Kankanhalli et al., 2005). We posit that the perceptions toward a particular KMS could be biased due to users' psychological commitments to other KMSs. Thus, frequent knowledge retrieval from a particular KMS that users perceive to contain high content quality may not necessarily lead to improved work efficiency. By examining knowledge workers' perceptions of three types of KMSs (an organization-created system and content, an organization-created system whose content is inputted by the knowledge workers themselves, and a self-created system and content) on their work efficiency, we confirm that knowledge workers' perceptions toward self-created KMS are biased. The knowledge workers have a positive bias on the search simplicity and content quality of their self-created KMSs, which leads them to frequently retrieve knowledge from their self-created KMSs, although, in reality, it does not significantly improve their work efficiency. This illusion of superiority of the self-created KMS may inhibit the knowledge workers from realizing the full potential of organization-created KMS that can actually improve their work efficiency.

7.2. Implications to practice

Organizations should not go the extra miles of populating content into the organization-created KMS. The reasons for this suggestion are twofold. First, the knowledge workers may not have a sense of ownership of the auto-populated content. Consequently, they may have a negative bias toward such a KMS. Second, the organization-created KMS should be integrated into the daily work activities of the knowledge workers in a way that, while doing their work, the knowledge workers are contributing knowledge to the KMS. For example, the call-center company embeds KMSone in the customer service employee's daily work. When responding to the customers' enquiries, the customer service specialists must type the enquiries and their responses into KMSone; hence, they routinely populate knowledge into KMSone.

Self-created KMS is unavoidable. It is not possible for organizations to prevent their knowledge workers from creating their own local knowledge repositories. Also, it is not possible for organizations to prevent knowledge workers from preferring their local knowledge repositories because of the positive bias of their self-created KMSs. What can be done is to integrate the knowledge workers' local knowledge repositories into the organization-created KMSs and maybe implement a ratings-based knowledge ranking as mentioned in Sutanto and Jiang's (2013) study. Therefore, the knowledge workers will access only one system when retrieving knowledge and the ranking system will help them access the best knowledge content that matches their needs. Over time, when the knowledge workers realize that the content of their local knowledge repository is inferior compared to the content of the organization-created KMS, they may no longer want to spend time creating local knowledge repositories.

8. Conclusion

Knowledge seekers are encouraged to actively retrieve knowledge from KMSs to obtain higher work efficiency. However, their knowledge retrieval activities from KMSs and subsequent effects on their work efficiency could vary depending on different types of KMSs. This study investigates knowledge seekers' knowledge retrieval activities and the work efficiency obtained from three types of KMSs: 1) an organization-created system that contains knowledge stored by the knowledge seekers themselves (KMSone); 2) an organization-created system with auto-populated knowledge content (KMStwo); and 3) a knowledge seeker's self-created system and content (LocalKMS). Knowledge seekers' content and process gratifications toward KMSone and the LocalKMS motivate them to actively retrieve knowledge from these KMSs. However, compared to KMSone, their positive perceptions of the LocalKMS are biased by their sunk costs of creating the LocalKMS, which, in turn, lead to frequent knowledge retrieval from the LocalKMS, although it does not necessarily translate into work efficiency. This study encourages future research to examine how to debias the perceptions of self-created systems. Moreover, the results of this study provide insights for organizations on KMS design so they will not overstretch their efforts in auto-populating content into organization-created KMSs.

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Periood	Kirjeldus
2014–...	Columbus Eesti AS; Ärilahenduste arhitekt (0,80)
01.09.2014– 30.09.2016	Tallinna Tehnikaülikool, Mehaanikateaduskond, Mehaanika ja tööstustehnika instituut; Insener (0,50)
2013	ETH Zürich; Akadeemiline külaline
2009–2016	OÜ IMECC; Ekspert (0,20)
2009–2014	Fujitsu Services AS; Ärilahenduste arhitekt
2007–2009	Ordi AS; Infosüsteemide juht
2006–2007	WM-data AS; Vanemprogrammeerija
1998–2006	Ordi AS; IT-juht
1996–1998	Tartu Kivilinna Gümnaasium; Infojuht ja arvutiõpetaja

Haridustee

Periood	Kirjeldus
2010–...	Tallinna Tehnikaülikool; Doktoriõpe
2013	ETH Zürich; Külalisdoktorant
2005–2008	Tallinna Ülikool; Tehnikateaduste magister (infotehnoloogia juhtimine)
2000–2005	Audentese Ülikool; Infotehnoloogia bakalaureus
1985–1996	Tartu Kivilinna Gümnaasium; Keskharidus

Teaduskraadid

Rivo Lemmik, magistrikraad, 2008, (juh) Priit Parmakson, OLAP kuubil rajanev infosüsteemi arendusmeetod, Tallinna Ülikool, Matemaatika ja Loodusteaduste Instituut, Informaatika osakond.

Teadustöö põhisuunad

VALDKOND: 4. Loodusteadused ja tehnika; 4.14. Tootmistehnika ja tootmisjuhtimine; CERCS ERIALA: T130 Tootmistehnoloogia

VALDKOND: 4. Loodusteadused ja tehnika; 4.7. Info- ja kommunikatsioonitehnoloogia; CERCS ERIALA: T180 Telekommunikatsioonitehnoloogia

Jooksvad projektid

F15027 "Tarkade tootmis- ja materjalitehnoloogiate arenduskeskus (1.09.2015−31.12.2022)", Kristo Karjust, Tallinna Tehnikaülikool, Mehaanikateaduskond, Mehaanika ja tööstustehnika instituut.

Lõppenud projektid

SF0140035s12 "Komposiit- ja funktsionaalsetest materjalidest konstruktsioonide, toodete ja tootmisprotsesside optimaalne projekteerimine (1.01.2012−31.12.2014)", Jüri Majak, Tallinna Tehnikaülikool, Mehaanikateaduskond.

SF0140113Bs08 "Mehhatroonika- ja tootmissüsteemide proaktiivsus ja käitumismudelid (1.01.2008−31.12.2013)", Mart Tamre, Tallinna Tehnikaülikool, Mehaanikateaduskond.

ETF7852 "E-tootmise kontseptsioon väike- ja keskmisega suurusega ettevõtetele (1.01.2009−31.12.2012)", Tauno Otto, Tallinna Tehnikaülikool, Mehaanikateaduskond.