UNIVERSITY OF TAMPERE
School of Management

UNDERSTANDING KNOWLEDGE WORK AND THE PERFORMANCE POTENTIAL OF ITS COMPUTERIZATION

CASE IBM'S WATSON

Business Management

Master's thesis

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Tutkimuksessa on keskitytty kehittämään tietotyön teoriaa ja analysoimaan nykyajan tietotyötehtävien automatisoinnin tarjoamia mahdollisuuksia tietotyön suorituskyvylle. Tutkimuksessa on kuvattu viiden tietotyöläisen työn sisältöä, muodostettu jäsennys tietotyötehtäville ja rakennettu viitekehys tiedollisille kyvyille, joita tietotyötehtävissä tarvitaan. Lisäksi tutkimuksessa on kuvattu IBM:n kehittämän uuden, kysymyksiin vastaavan Watson-tietokoneen teknologisia ominaisuuksia yleisellä tasolla, sekä analysoitu Watsonin tiedollisia kykyjä ja suorituskykypotentiaalia tietotyötehtävissä.

Tutkimuksen kirjallisuuskatsauksessa on käsitelty informaation ja tiedon luonnetta, tietotyötä, sekä tietotyön suorituskykyä ja tuottavuutta. Lisäksi siinä on esitelty kaksi kognitiivista mallia, jotka auttavat ymmärtämään mielen toimintaa. Vaikka monet tutkijat ovat tutkineet tietotyötä, ei selkeää ja yhteneväistä määritelmää käsitteelle ole vakiintunut.

Tutkimus toteutettiin laadullisena case-tutkimuksena ja grounded theory -metodilla. Laadullisella case-tutkimuksella on kuvattu ja selitetty tutkimuksen monitahoista aihetta. Grounded theory -metodia on sovellettu teoreettisen viitekehyksen rakentamisessa. Empiirinen aineisto koostuu viiden tietotyöläisen ja yhden teknologia-asiantuntijan haastatteluista, jonka lisäksi on käytetty Watson-tietokoneeseen liittyvää julkaistua aineistoa. Haastattelumateriaalia on tutkittu induktiivisella sisältöanalyysillä kategorisoimalla tietotyöntekijöiden työt rooleihin ja tehtäviin. Kirjallisuuskatsauksessa esitellyt Spaun-malli ja COGNET-viitekehys ovat toimineet älyllisinä oppaina rakennettaessa tiedollisten kykyjen viitekehystä. Watsonin teknologiaa ja kykyjä on kuvattu yleisellä tasolla julkaistun aineiston pohjalta, jonka jälkeen sen tiedollisia kykyjä on arvioitu tarkemmin asettamalla aineisto tutkimuksessa rakennettuun tiedollisten kykyjen viitekehykseen.

Tämän tutkimuksen keskeisimpiä tuloksia ovat tietotyötehtävien jäsennys, tiedollisten kykyjen viitekehyksen rakentaminen, sekä Watsonin suorituskykypotentiaalin analysointi eri tietotyötehtävätyypeissä. Watsonin suorituskykypotentiaalianalyysin tulokset viittaavat siihen, että sen suorituskykypotentiaali on suurinta kysymyksiin vastaamisessa, analysointityökalujen käyttämisessä, informaation levittämisessä, tiedon pyytämisessä, sekä delegoinnissa. Tulosten mukaan alhaisin potentiaali sillä on puolestaan keskusteluiden ohjaamisessa, ideoiden ja ratkaisuvaihtoehtojen synnyttämisessä, suostuttelussa ja neuvottelussa, sekä yhteisessä keskustelussa ja päätöksenteossa.

ABSTRACT

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This study focuses on theorizing knowledge work and studying the performance potential of computerizing contemporary knowledge work tasks. In the research, the job content of five knowledge workers is described, classification for knowledge work task is formulated, and a framework for knowledge capabilities required in performing knowledge work tasks is constructed. Furthermore, the technological properties of IBM's new questions-answering computer, Watson, are described in general and its knowledge capabilities and performance potential in knowledge work tasks are analysed.

The literature review of this research concerns the nature of information and knowledge, knowledge work, and knowledge work performance and productivity. Moreover, two models on cognition are presented that help understanding the mind. Despite the fact that knowledge work has attracted numerous scholarly minds, no clear and concise definition exists.

The research was conducted using the methods of qualitative case study and grounded theory. Qualitative case study has been used to describe and explain the multifaceted phenomenon. Grounded theory method has been applied in constructing the framework in the study. Empirical evidence is based on the interviews of five knowledge workers and a technology expert as well as on relevant published data on Watson. Inductive content analysis has been used to study the interview material by categorizing the jobs of the knowledge workers into roles and tasks. The Spaun model and COGNET framework presented in the literature review have worked as intellectual guides in constructing the knowledge agent's knowledge capabilities framework applied in the analysis. Descriptions on Watson's technology and capabilities are based on published material and its knowledge capabilities have been analysed by using the knowledge capability framework.

Among the key results of this study are the formulation of knowledge work task typology, the construction of framework for knowledge capabilities, and the analysis of Watson's performance potential in various knowledge work tasks types. The findings of Watson's performance potential analysis suggests that it has the greatest performance potential in the task types of answering questions, using analyzing tools to create information and insights, information disseminating, requesting information and delegating. Its lowest performance potential is in the task types of directing discussion, generating ideas and alternative solutions, persuading and negotiating, and discussing and deciding together, according to the results.

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1 INTRODUCTION

1.1 Studying knowledge work and the performance potential of its computerization

> *"To make knowledge work more productive will be the great management task of this century, just as to make manual work productive was the great management task of the last century." —Peter F. Drucker (1978)*

I remember asking my teacher during an Economics lesson in High school: "What is it that all those people do in those office buildings that are scattered around city centres. They say that all the best jobs are found inside them, and still I have no clue what is happening there." Being somewhat struck by the rather odd question, my teacher could not come up with any answer to my question. Now almost ten years later and still being intrigued by this question, I have gained a vague idea through work experience and academic study of some of the things that people do inside those buildings. Besides that, I have come to realize the importance of knowledge and information for today's organisations.

Historically, economic development has been largely credited with the increase of productivity (e.g. Roubini and Backus, 1998). Marx and Engels (e.g. 1846) went so far as to claim in their *material conception of history* that the most important moving power of all economic development of society is the changes in the modes of production and exchange, which are based on technology, productive capacity, and the division of labour. With the pioneering work of F.W. Taylor's work study and Scientific Management, the 19th century industrial fantasy of increasing the productivity of manual work was achieved in the course of the 20th century as industrialized economies were able to rise their industrial productivity level to at least 50-fold, resulting in the remarkable rising living standards in the industrialized countries and the birth of the modern material abundance and consumerism that we witness today. The secret in Taylor's work was to study manual work productivity systematically. (see Drucker, 1978, 1999; Lebergott 1993).

As the share of knowledge workers has grown in the labour force, especially in the developed countries (see Davenport, 2005; Haag et al., 2006), there is a growing need to increase the productivity of knowledge work, too (e.g. Drucker 1978, 1999; Davenport, 1998). Towards the end of the 20th century, some productivity development initiatives have started to emerge in knowledge work, in particular with the advancements in ICT, but a productivity revolution in knowledge work similar to that of manual work has yet failed to manifest itself and is still to be borne by the endeavours of the 21st century (Drucker, 1999). Just like Taylor recognized the importance of studying manual work some hundred years ago, Davenport (1998) has discussed the necessity of concentrating on knowledge worker productivity and to better understand knowledge work processes through studying individual work actions. This calls for new typologies and frameworks for knowledge work (see Reinhardt et al., 2011).

Throughout the era of civilization, tools have changed the way people do and perceive work (e.g. Marx and Engels, 1846). Excavators replaced people with shovels, printing presses took the place of people with pens, and automobiles made horses with carriages obsolete as a means of transportation (see Febvre and Lucien, 1976; Mokyr, 2004; Alexander 2011). In the context of knowledge work, telephones, computers, mobile phones, and e-mail have changed the way knowledge workers process information and communicate, whereas the Internet and services like search engines, such as Google, or collaborative encyclopaedias, such as Wikipedia, have changed the way people search for information (see Constable and Somerville, 1964; Friedman, 2005; Tapscott and Williams, 2006).

Now, a new class of technology, question-answering computer systems, is emerging, as IBM has developed an artificially intelligent computer system named Watson. Watson's newly developed DeepQA software enables it to answer natural language questions using large databases composed of structured and unstructured data such as natural language. It could usher in a new genre of knowledge work tools for, not just finding information, but also finding accurate answers fast. Watson managed to prove its capabilities by winning the best human players in the popular Jeopardy game show already in 2011. IBM has publicly stated that Watson is already being utilized in assisting doctors in conducting medical diagnosis. (Peltola, 2011, IBM's website).

Whereas search engines, like Google search, have allowed people to find relevant content with lightning speed, the emerging question-answering technologies enable people to save time by going through vast amounts of content and extracting from it answers to questions (Peltola, 2011). According to McDermott (2005), searching for information takes 38% of time in knowledge work. These technologies have revolutionized the way people can access information sources and finding relevant information. This in turn has lead to the democratization of valuable information, which will have a tremendous effect on the competitive advantage of large organisations, as smaller companies as well as customers now have access to more and more of the same information that previously was exclusively available to few organisations and few individuals. It also allows for individual professionals to network, collaborate and organise in new ways, as they are becoming less and less dependent on organisations as stocks and providers of relevant information. (see Hagel, Brown & Davison 2010; Gray 2012).

However, automated question answering using vast databases is not the only important change factor here. In fact, the information processing capabilities built in Watson to extract answers to questions are comparable to many cognitive capabilities of humans (IBM's website), which means that a whole range of tasks in today's knowledge work—thus far performed by humans and their brains, in particular—could be handed over to be performed by machines.

In this research project, I have studied both knowledge work as well as the performance potential of computerizing that work with artificially intelligent computer systems. Watson, the case technology of this research project, possesses knowledge capabilities that have not previously been seen in computers (IBM's website). This technology will in the near future have a major impact on both knowledge work content and knowledge work performance levels through automation (Peltola 2011, IBM's website).

1.2 Objective of this research

The research objective of this study is first *to increase the understanding of contemporary knowledge work by formulating a typology of key knowledge work tasks and a framework of knowledge capabilities,* and secondly, *to analyse the potential in computerizing contemporary knowledge work tasks*. To reach this research objective, I have ventured to answer the following research questions:

- to describe empirically the work roles and tasks of five contemporary knowledge workers
- to formulate a typology of main task types in contemporary knowledge work
- to construct a framework for knowledge capabilities utilized in performing contemporary knowledge work tasks based on the empirical data on the tasks and existing theorization
- to empirically reflect which knowledge capabilities were required in conducting the task types and to count in how many task types they occurred in total
- to describe the technology of Watson (and its DeepQA software) in general and what knowledge capabilities it possesses in terms of the new framework
- and finally, to analyse Watson's knowledge work performance potential in relation to the knowledge work task types by counting the coverage of its knowledge capabilities in each knowledge work task type

1.3 Methodology

1.3.1 Qualitative case-study

I have chosen qualitative case study as the method for this research project. According to Hirsjärvi, Remes & Sajavaara (2009) qualitative case study endeavours to deepen the researcher's understanding on the subject by studying it in a rich and comprehensive way. It is not, thus, utilized for testing a hypothesis. As the subject under examination can be characterized as a complex and multifaceted phenomenon, this method seemed appropriate.

Koskinen, Alasuutari & Peltonen (2005) maintain that besides being among the most frequently used ways to do research on business, case study can be more precisely considered as an approach rather than a method, as there is no single right way of conducting it. For the purpose of constructing a broad understanding on a specific subject of study, the common objective is to garner rich and deep insights into one or more cases. As a result, some general statements can usually be formed about the subject, given that there is a multifaceted and profound understanding.

In the discussion part of this research, I have evaluated the trustworthiness and generalizability of the this study, since an essential property of a qualitative study is that its reliability cannot be tested statistically (Kyngäs and Vanhanen (1999). Therefore, I have described the research process and methodology in great detail and thoroughly used reference citations for this purpose, as according to Eskola and Suoranta (1999), this allows the reader to judge the reliability of the research and paves the way for critiquing the arguments of the researcher.

1.3.2 The concept of framework and grounded theory method

According to Jabareen (2009), the present usage of terms *conceptual framework* and *theoretical framework* are ill-defined and unclear. To tackle this indistinctness, Jabareen (2009) defines conceptual framework as a "network, or a plane, of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena." Conceptual frameworks have ontological, epistemological, and methodological suppositions, and every concept within a conceptual framework plays an ontological or epistemological part. Jabareen (2009) elaborates that the ontological suppositions relate to knowledge of the "way things are," "the nature of reality," "real" existence, and "real" action. The epistemological assumptions associate with "how things really are" and "how things really work" in a presupposed reality. The methodological suppositions associate with the process of constructing the conceptual framework and evaluating what it can reveal about the "real world. Jabareen (2009) argues that grounded theory method is sufficient and extremely practical for building conceptual frameworks, because it is a specific paradigm of inquiry that incorporates numerous different characteristics and involves the use of coding paradigms to guarantee conceptual development. It is a research method intended at the discovery of theory from data obtained in a systematic way. (Jabareen, 2009).

According to Gibbs (2010, a), the generation and introduction of grounded theory is accredited to two American researchers, Barney Glaser and Anselm Strauss. Grounded theory is "shaped by the desire to discover social and psychological processes" (Gibbs, 2010, b). Allan (2003) explains that grounded theory is a research method that can be considered working practically reversed way from conventional social science research. Instead of commencing with a hypothesis, the first course of action is data collection, through a selection of methods. The key points are labelled with a series of codes from the data collected that are extracted from the text. To make the codes more workable, they are grouped together into equivalent concepts. Categories are formulated from the concepts, which provide the foundation for the formation of a theory, or a reverse engineered hypothesis.

Grounded theory is contradictory to the traditional model of research, in which the researcher elects a theoretical framework, and only then utilized the model to the phenomenon to be researched. Allan (2003). Glaser & Strauss (1967) state that instead of aiming for the "truth", grounded theory works toward conceptualizing what is happening by using empirical research. It may be stated that, grounded theory is similar to what a number of researchers do when formulating new hypotheses to match data retrospectively. The researcher, however, does not produce the hypotheses beforehand as preconceived hypotheses lead to a theory that is not grounded from the data. Glaser & Strauss (1967). Glaser devised the basic process of grounded theory method depicted as the continual comparative method where the researcher commences analysis with the initial gathered data and continually compares indicators, concepts and categories as the theory emerges.

1.3.3 Sources, data gathering, constructing a framework, and analysis of empirical evidence

Sources of empirical data

The empirical material of the research was composed of one expert interview on DeepQA computer systems (Watson) and of five knowledge worker interviews about their work, of IBM's own publications on Watson, and of a set of published articles and columns on Watson on the Internet.

The expert interview was conducted with IBM Finland's innovation manager, Ville Peltola. The five interviewed knowledge workers all have an academic education, which is often required in knowledge work jobs and, as Multisilta and Paajanen (2006) argue, is highly related to contemporary knowledge work. Because I wanted focus on knowledge work in general and not just on the management side of it, I chose knowledge workers who were not predominantly in managerial positions. That is to say in Mintzberg's (1973, 2009) terms, they were not heading any units and did not have direct subordinates working under their command, although one of them was assigned to as the manager of a project. According to Reinhardt et al. (2011), one of the main factors that differentiate knowledge work from other forms of work is its primary task of "non-routine" problem solving. For this reason, I chose knowledge workers whose jobs included projects, as today's knowledge work is to a large extent organised in projects and accomplishing projects involves often uncertainty and requires evaluation, decision-making, and creativity, which are characteristic for knowledge workers with academic background.

In order to increase generalizability of my empirical findings, the knowledge workers were from different companies. Two of them were which two operate in the Internet business, one was in oil procuring industry, one was in machine engineering, and one was in IT solutions industry. All but one of the companies operated multi-nationally.

Data gathering

The interviews were conducted by using half-structured thematic interviews. Thematic interviews can be considered appropriate for this study, for they give the interviewees the opportunity to describe and explain a multifaceted phenomenon using their own words. I chose the themes for these interviews only after having familiarized myself with the research literature and after reading a significant amount of published data on both Watson and its DeepQA software.

I built the structure of the thematic interviews so as to leave out as many personal prejudices as possible and to not restrict the responses of the interviewees. This does not mean that I dismissed the theoretical background about knowledge work completely, as I had familiarized myself with literature on knowledge work and cognitive psychology, namely the COGNET framework by Zachary, Ryder, and Hicinbothom (1998), which relates cognitive psychology to knowledge work. The theoretical background worked as a guiding force in creating research questions and carrying out the interviews. Eskola and Suoranta (1998) state that the task of the interviewer is to steer the interview according to the predetermined themes, but at the same time to consider the factors relating to the interviewee. The structure of the thematic interview was to assure that the same subjects were discussed with all interviewees. To achieve this, I used the readily prepared questions as a guide for carrying out the interviews in a fashion that fitted the interviewee and one's job context. The main structure guiding the knowledge worker interviews was the request to describe their job in a manner that divided their jobs into various roles and tasks.

Before analyzing the material, I transliterated it word-by-word right after the interviews. Altogether there are 100 pages of interview material. I processed the transliterated material from a factual point of view. According to Koskinen et al. (2005) it is when the interviewees' verbal descriptions and explanations about the subject and the phenomenon are considered factual *per se*. Thus, the purpose of the interviews was to find out how the interviewees perceive or experience the phenomenon under study, in the case of this study their own work. The factual perspective must not be confused with the concept of truth. This means that the conceptions that arose during the interviews were treated critically, but whose truthfulness was not doubted to an unnecessarily high degree. (see Koskinen et al. 2005)

Constructing a framework using grounded theory

For the purpose of analyzing what knowledge capabilities the different task types required and what knowledge capabilities Watson might possesses, I built a framework comprising of knowledge agent's knowledge capabilities. To construct this framework, I analysed a total of 104 different tasks and 25 task types. I then reflected on what actions were involved in conducting them based on my extensive readings on knowledge work and related theories. Then, with the help of having familiarized myself, although not restricting, with literature on cognitive psychology, the COGNET framework, and the Spaun model, I produced a list of knowledge capabilities that I thought were required in conducting the tasks and gave definition to each of them. After going through the list of knowledge capabilities and reflecting on their relation to each other, I constructed categories of these knowledge capabilities and finally integrated these categories into a framework that depicts a general capability blueprint for knowledge agents performing knowledge work, that is, to receive, to process, and to communicate information, and to operate on information using knowledge and knowledge capabilities.

In the final phase of my analysis, I went through all the task types again. After forming a clear picture of the actions that each of these types of tasks consisted of, I reflected on what knowledge capabilities had been required to perform the actions in the 25 task types and in what way they had been utilized. According to the published data, I then analysed what knowledge capabilities Watson possessed and converted them into knowledge capabilities to fit into my framework. Next, I compared Watson's newly defined knowledge capabilities with the required knowledge capabilities in the task types and formed an evaluation on how largely Watson's knowledge capabilities cover the required knowledge capabilities in those task types that had been formed from the tasks of the five knowledge workers interviewed.

Analysis of empirical evidence

After dissembling the interviews, I analysed the material content with content analysis methods as systematically and objectively as possible. According to Kyngäs and Vanhanen (1999), with content analysis the gathered material and studied phenomenon can be organised, described, or quantified. The purpose of the analysis is to build models that depict the described phenomenon in a condensed form and with which the phenomenon can be conceptualized.

I started the analyzing phase by familiarizing myself with the material by reading it through a few times. According to Kyngäs and Vanhanen (1999), in the first phase it is pivotal for the researcher to define the unit of analysis and its size between word (or word combination) and syntax (or conceptual entity). In this study, I used syntax as the unit of analysis, because in the thematic interview the interviewees described their work and organisation in their own unique ways and words, for why it was necessary to focus on the meaning of the sentences they uttered during the interviews. I conducted the content analysis inductively, that is, I began with the material. Contrary to deductive analysis, inductive analysis is not directed by ready-made structure of an analysis based on earlier theorization, but is based on the relevant syntax. Conceptual entities were drawn from the material according to the research objectives (Kyngäs and Vanhanen 1999). I justify this choice by stating that the purpose of this study was not to test earlier theoretical knowledge and conceptual systems, but to describe and understand the studied phenomenon.

According to Kyngäs and Vanhanen (1999), categorizing can be considered form of a content analysis, and it can be divided into three phases: reduction, grouping and abstracting. In the reduction phase, I coded conceptual entities relevant to the studied phenomenon from the material. I conducted this by examining the knowledge worker interviewees' accounts on their job roles and discerning individual tasks from them. Then, in the grouping phase, I merged similar tasks into task types, and worked on to label the entities with names depicting the task types as well as possible. Finally, in the abstracting phase, I categorized the various task types into task categories until categories depicting the phenomenon were formed. I posed questions to the material relevant to the study and wrote down the answers.

The empirical emphasizing content analysis of this research can be described according to Figure 1:

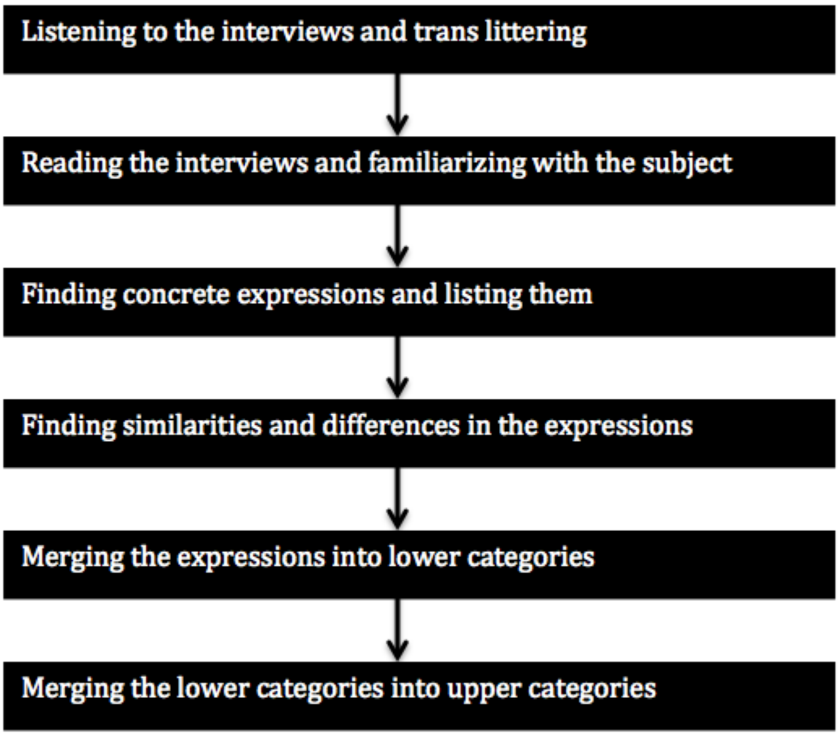

Figure 1 Phases of empirical content analysis (adopted from Tuomi & Sarajärvi 2003)

After the inductive empirical analysis, I moved on to the interpretation phase, where I compared my results with the earlier research. According to Koskinen et al. (2005) discussion between theory and empirical material is the only aspect distinguishing everyday thinking from research.

1.4 Key concepts

Knowledge

In this research, knowledge refers to the capability to store and interpret information according to different frameworks that allows processing it in a particular way with different knowledge capabilities. It provides a model and logic to perceive the environment, and thus enables operating in it in a way that is relevant to the values of a knowledge agent. In this study, knowledge also refers to one of the central knowledge capabilities.

Knowledge capability

In this research, I define knowledge capability as a resource of a knowledge agent that enables it to process information. Interpreting natural language, inference, and producing natural language are examples of knowledge capabilities. Knowledge capabilities are based on cognitive capabilities. The term may be applied to both humans and computers / machines alike. One should note that the concept capability differs from the concept of task or task type, in the manner that capabilities are resources to be utilized in performing tasks.

Knowledge work

Knowledge work is a general term for labour that is mostly related to processing information. Its main types in this study are receiving, processing, communicating information, and operating using knowledge. Knowledge work can be considered all the work that is not mainly associated with physical labour or routine interaction with people such as clerical work. Knowledge worker is a person doing knowledge work. Manager, lawyer, salesman, and engineer are general types of knowledge work jobs. For instance, in the spirit of Henry Mintzberg, managers are knowledge workers that are responsible of a unit and have subordinates to whom they can assign tasks and responsibilities. (Mintzberg, 1973; 2009).

Knowledge agent

Knowledge agent is defined here as an entity that has knowledge capabilities, some level of knowledge, and is capable of processing information for the purpose of accomplishing tasks. It may refer to a human, in which case knowledge worker is an appropriate term, or it can mean a computer or a machine like Watson, an artificially intelligent computer system, which is used as the case technology in this study.

Knowledge work performance

Knowledge work performance is defined here as the measure of knowledge worker effectiveness to set and define his or her own tasks in a way that best serves the organisational process in which his or her role belongs to. Consequently, it is the degree of aptitude to manage his or her time, effort and competence to serve one's purpose in an organisation. It includes also the efficiency or the speed and quality at which the knowledge worker is able to accomplish the self-assigned tasks and routine knowledge work processes. Performance should not be mixed with productivity, although the two concepts are closely associated. The former refers to the more general capacity to create value, whereas the latter is more concerned with efficiency of production.

Role

A role in this study is a position of a human knowledge worker or some other knowledge agent (e.g. computer), which consists of a set of tasks that are expected of him/her/it in order to participate in some organisational process. A knowledge worker or a computer must have the necessary capabilities to perform in a role that consists of a set of tasks, and the talent or proficiency in order to perform well that role.

Task and task type

In this research, I have defined task as a sequence of activities for the purpose of achieving some desired outcome. In this study it is used more widely to describe a goal that can be carried out in many different ways that are appropriate for the situation. Task type refers to a category of tasks. As noted earlier, one should not confuse the concept of task with capability, as the former refers to a job to be done and the latter to resources of an agent to be utilized in performing tasks.

1.5 Structure of this research project

This research project is divided into seven Chapters. The first Chapter is the introduction, where I lay the foundation for the study. It consists of the research objectives and questions, description of the methodology and justifications for the methodological selections, definitions of the relevant concepts of the study, and the structure of the research project.

In the second Chapter, I go through the academic literature that has been written about information and knowledge, knowledge work, knowledge work performance and productivity, and cognition.

In the third Chapter, I introduce five knowledge workers and give an elaborate description of the work they do in their organisations based on interviews. A subchapter is dedicated for each of the interviewees.

In the fourth Chapter, I introduce a knowledge capability framework for a knowledge agent, which I built based on the descriptions of the knowledge workers in the previous Chapter and theoretical models in the second Chapter. I use this framework later on as the basis of analysis.

In the fifth Chapter, I give an account of IBM's Watson and its underlying DeepQA software. I portray a model of the technology that helps the reader to grasp what the technology is based on and what capabilities it possesses.

In the sixth Chapter, I synthesize the theory with the empirical material. Here, I present the analysis of the tasks and roles the jobs of the five knowledge workers consist of. I then formulate task types from the tasks, and task categories from the task types. Next, I reflect what knowledge capabilities were required in the task types. After that, I analyse using my framework which of the knowledge agent's knowledge capabilities IBM's Watson possesses. Finally, I conclude this Chapter by specifying IBM's Watson's knowledge capability coverage in the task types.

Finally, in the seventh Chapter I draw conclusions from the previous Chapters. I evaluate the implications of the results and then discuss what it could mean for the future of knowledge work and organisations in general. I also discuss the limitations of my research and give recommendations for future research.

2 LITERATURE RELATED TO KNOWLEDGE WORK

In this Chapter, my aim is to review the literature relating to information and knowledge, knowledge work, and its subcategory managerial work, and knowledge work performance and productivity. In the last part, I present two models related to cognition.

2.1 Knowledge and information

Throughout the decades of the latter half of the 20th century, there has been a conceptual confusion regarding knowledge, information and knowledge work. Brinkley, Fauth, Mahdon and Theodoropoulou (2009) argue that one of the problems in defining knowledge work has been the difficulty to define 'knowledge' itself and defining knowledge apart from information. They state that resulting from this, for instance, the two terms 'information worker' and 'knowledge worker' can be used similarly.

Likewise, Wilson (2002) stresses that the ambiguity between the meaning of the terms 'knowledge' and 'information' that is present in the work of management researchers and other literature causes much unnecessary confusion. According to Wilson (2002) the two terms are often used as synonyms, and it is the duty of academia to form a clear distinction between the two. In his view, it is rather easy to distinguish these two concepts and thus show the meaninglessness of the widely used concept 'knowledge management' that he so eagerly criticizes in his article. Wilson (2002) defines 'knowledge' as follows:

> *"Knowledge is defined as what we know: 'knowledge involves the mental processes of comprehension, understanding and learning that go on in the mind and only in the mind, however much they involve interaction with the world outside the mind, and interaction with others."* (Wilson 2002)

Wilson (2002) explicates that whenever we express what we know, we never carry knowledge itself, but utter messages of various kind, such as oral, written, graphic, gestural and 'body language'. The messages themselves do not convey 'knowledge', but compose of information that a knowledgeable mind can assimilate, understand, comprehend and incorporate into its structures of knowledge. The knowledge structures of the person uttering the message and the one receiving it are not identical, but are uniquely determined according to the course of a person's life. Hence, the message never lights the same understanding or builds the same kind of knowledge in the receiver as the knowledge base[1] where the message originates (Wilson 2002). Similarly to Wilson, Brinkley et al. (2009) maintain that what separates knowledge from information is that the former is a matter of active cognitive ability that enables agents to do and reflect, whereas the latter is, on the contrary, passive and meaningless to those without relevant knowledge. Knowledge is the way to interpret information and bring it to life (Brinkley et al. 2009). Wilson (2002) goes on further with his definitions and states that everything that is outside the mind and that can be manipulated is either 'data' or 'information'. The difference between these two is that the former constitutes simple facts, and the latter is data that are embedded to the recipient with relevant context.

Another conceptual division can be found between 'tacit' and 'codified' knowledge (see Jensen et al. 2007). The latter represents something that can be written down, for instance, in manuals, guides, instructions and statements and is effortlessly copied. By contrast, tacit knowledge is embodied in the individual in the form of experience and skills that cannot be written down and passed on easily to other people. Hence, in Jensen's et al. (2007) terms codified knowledge and information are much identical concepts. The essential distinction can therefore be found between tacit knowledge and information (Brinkley et al. 2009). Wilson (2002) however argues in his article, where he criticizes knowledge management literature, that the word 'tacit knowledge' has been used falsely for decades as the term, originally coined by Polanyi (1958) has been described as follows:

> '*the idea that certain cognitive processes and/or behaviors are undergirded by operations inaccessible to consciousness'* (Polanyi 1958)

Here, the key point that Wilson (2002) attempts to suggest is that tacit knowledge is hidden and therefore beyond the awareness of even the knowledgeable agent. That is why Polanyi (1958) used in Wilson's (2002) view the expression 'We can know more than we can tell.' However, Grant et al. (2007) point out in their meta-analysis on the use of Polanyi's work in scientific literature that the most frequent misinterpretation of Polanyi is the suggestion that he identified two separate sorts of knowledge—tacit and explicit—that only occur in either/or state. Grant et al. (2007) claim that what Polanyi really meant was that all knowledge has a tacit element and it is only the degree of tacitness that varies. They present

[1] Interestingly Wilson uses here the word 'knowledge base', which in this case implies to humans, but the term can also be found in the field of computer science referring to organisation's information systems. In this study, I shall use the term "knowledge agent" henceforth.

Polanyi's expression of the concepts of tacit and explicit knowledge in the following diagram, displayed in Figure 2.

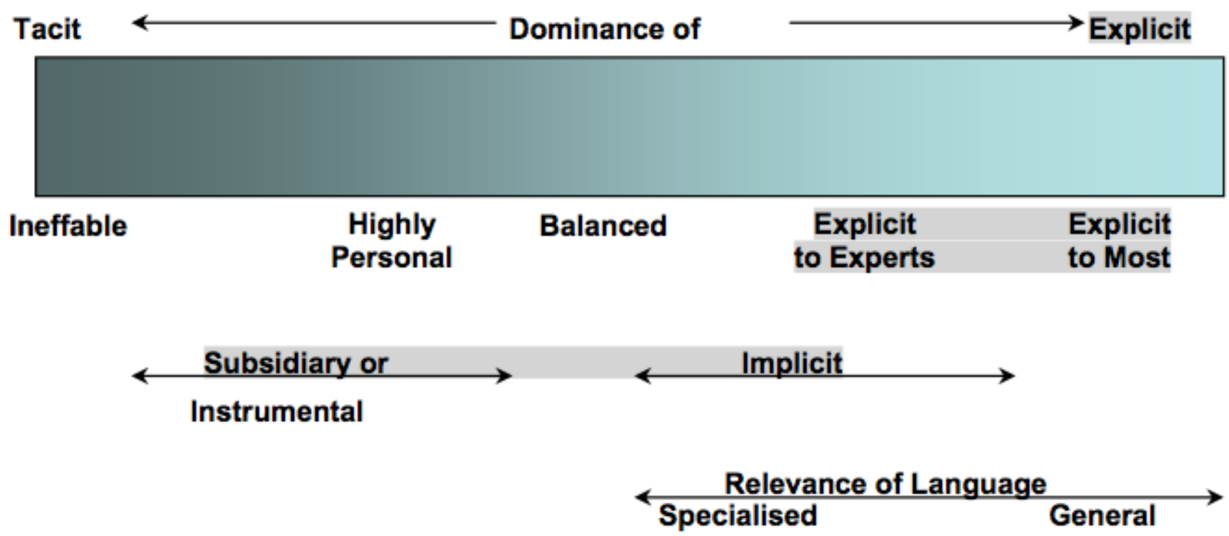

Figure 2 The Tacit/Explicit Dimension, derived from Polanyi (Grant et al. 2007)

Grant et al. (2007) show in the diagram Polanyi's essential principle that tacit knowledge is present at all degrees of knowledge with varying dominance. The continuum spans from a situation, where there is hardly any tacitness to knowledge, and it could be accepted widely by many people, with little background experience; through a situation, where experts may share the knowledge considering their common background, education, training and experience; to the situation, where the knowledge is highly personal and difficult to articulate to even people with the same background; and, eventually to the 'ineffable' knowledge that remains beyond the awareness of even the knowledgeable agent with the knowledge. The use of language is closely related with the degree of explicitness of knowledge. In the explicit end, there is wide acceptance of the use and specificity of the language among a large number of various people. When there is an advanced level of knowledge, the level of shared tacitness increases and the use of language excludes non-experts to whom the language has meaning. Grant et al. (2007) propose that the knowledge 'explicit to experts' level could be interchanged by the term "implicit knowledge", which they say has been used often in the literature, but was never discussed by Polanyi himself. In their view, 'implicit knowledge might be described as tacit knowledge that could be made explicit but need not be in a community that shares a common view of the necessary tacit knowledge. (Grant et al. 2007.)

2.2 Knowledge work

The term 'knowledge work' has been widely used in literature and media, but the concept has lacked a clear and concise definition, despite the fact that many researchers have puzzled it over for a number of decades (Pyöriä 2005). The term 'knowledge work' is often credited with Peter Drucker, although it was Fritz Machlup (1962), who originally introduced the concept as he identified a large body of knowledge-based activities, when observing change in American society and economics. Peter Drucker (1969) and Daniel Bell (1973) then marketed the concept outside the academic world. At the same time and independently from their American colleagues, researchers in Japan forecasted the emergence of an information society and developed their own methodology for quantifying information streams across society's communication channels (Pyöriä 2005).

According to Pyöriä (2005), the latter half of the 20th century shows a significant rise in the production and consumption of information goods and services. Communication systems form one of the fastest growing and most important constituents of most nations' economies. As it has been estimated that the volume of information available for people doubles every 20 months (Frawley et al. 1992), there is a clear need for communication systems and information goods and services. Furthermore, there is evidence of the development of western labour markets, which has seen the rise of the knowledge worker, a critical factor distinguishing the competitive economies from the rest. These economies demand workforce with high education level and skills that add to the value of products and services. (Pyöriä 2005.)

Pyöriä (2005) points out that as the importance of knowledge as an economic resource has grown larger together with the development of the economies and technology, coordination costs have risen as a result of increased complexity and specialization. As a consequence, it takes more communicative effort for organisations to manage their productive systems and processes. With this development the greater demand for informational labour has followed that is capable of handling, synthesizing and creating new knowledge, when at the same time there is ever diminishing need for traditional manual work, which is vulnerable to automation. (Pyöriä 2005.)

As shown earlier by Wilson (2002) and Brinkley et al. (2009) the distinction between information and knowledge is that the previous is passive and meaningless to a person without background experience and relevant knowledge for understanding, and the latter is active that gives the means to a knowledgeable agent to reflect and act. Thus, one can conclude that 'information worker' as a term emphasizes what the worker processes, which is information, whereas the term 'knowledge worker' underlines what the worker has, which is internal capabilities and resources, that is knowledge, that he or she wields to process information. In other words, an information/knowledge worker works on information with knowledge. One way or the other, it doesn't change the implications, whichever term one chooses to use. Having said this, we can extrapolate that computers too have knowledge, as they have the capability to process information in various ways according to their programming, although, currently in far less complex ways than humans.

Drucker (1999) approaches the definition of knowledge work broadly by comparing it to physical work. In his view knowledge work can be understood as work, where processing information has a central role. According to Drucker (1999) knowledge work is also characterized by independence and innovativeness. Thus in his view the work of an artisan, for instance, is not to be considered as knowledge work, because it does not involve information processing, whereas the work of a nurse has many aspects of information processing that occur in handling patient information. Although this delineation is useful, Drucker didn't go on to identify widely the jobs that fall into this category (Brinkley et al. 2009.)

Davis & Naumann (1999) define knowledge work as "human mental work performed to generate useful information." In doing so, knowledge workers access data, use their knowledge, employ mental models, and utilize concentration and attention in great lengths. Knowledge work then culminates in useful information and involves series of proceedings for acquiring knowledge, designing analyses and solutions, making decisions, and communications. Activities that count as examples include scanning and monitoring information sources, searching for information, modelling problems and processes, planning, organising, scheduling, authorizing outputs, formulating problem definitions, performing analyses, selecting among alternatives, formulating action plans, presenting analyses, presenting results of analysis, and persuading and motivating others to accepts analyses and plans. Managers, analysts, authors, developers, planners, and so forth are all examples of knowledge workers. However, knowledge workers never do only knowledge work, because clerical work, like typing, must always be performed in order to do knowledge work. As a consequence, knowledge worker is just someone whose job is dominated by knowledge work. (Davis & Naumann 1999.)

According to Lazzarato (1996) knowledge work is immaterial work. He defines immaterial work as work, which produces informational and cultural content to a product. Information processing and communication characterize informational work. According to Lazzarato (1996) immaterial work contains, e.g., activities that relate to setting and modifying cultural and artistic standards, fashion, consumer norms, and more strategically public opinion.

Multisilta & Paajanen (2006) maintain that knowledge work can be divided into routine and creative knowledge work. According to Siltala (2004), a significant share of knowledge work is routine knowledge work. Multisilta & Paajanen (2006) suggest that the most central criteria of knowledge work are the use of information technology, planning required to do the work, and related to these criteria, education.

Autor, Levy, and Murnane (2003) were interested in computerization of work. They regrouped existing statistical occupational codes and formed five groups based on the degree of adherence to strict rules and computer substitutability for work, both of which mark the degree of routine work. The groups were as follows:

1. *Expert thinking:* covers problem solving beyond solutions based on rules, with computers complementing but not substituting. In addition to high level research and creative work, it includes mechanics that are able to identify solution to a technical problem that computer-based diagnostics system cannot.
2. *Complex communication:* covers interacting with people to acquire and convey information and persuade them with computers complementing, but unlikely substituting. The work of some managers, teachers, and salespeople belong into this group.
3. *Routine cognitive:* Covers mental tasks that abide by closely described rules, like routine form processing and filling. Many times susceptible to computerization.
4. *Routine manual:* Covers physical tasks that abide by closely described rules, like assembly line work and packaging. Susceptible to be replaced by machines.
5. *Non-routine manual:* Covers physical tasks, which are hard to define and require constant consideration from the worker, because they involve fine coordination of eyes

and muscle control such as truck driving and cleaning. According to Autor et al. (2003) these tasks are unlikely to be either complemented or substituted by computers.

According to Brinkley et al. (2009) this delineation helps generate understanding on the workers' input and on the susceptibility of various types of roles to massive scale computerization enabled substitution. Expert thinking, complex communication and analytical reasoning, which can be defined as an ability to make oral or written arguments, are the way to defining knowledge work. The counterpart then is formed by work that is routine-cognitive, routine manual, and non-routine manual. Hence, knowledge work is more than just basic information processing that adheres to strict rules. In their terms, computers can complement, but cannot replace knowledge work. (Brinkley et al. 2009.) Nevertheless, this view can be disputed, as so far no one has been able to prove that there are limits to how far computer technology can develop. In theory, computers could be developed to the degree of having all the capabilities that humans have, and therefore replace human labour altogether in the economy as a means of production, albeit this is currently unfeasible.

A report by Brinkley et al. (2009) used statistical analysis in their study on knowledge work. They found a gap in knowledge work research, as the studies that had been done involved only conceptual, data-driven and job-content definitions of knowledge work, but lacked more detailed focus on the tasks and activities of nations' workforce. Using a list of 186 different tasks, they conducted a survey in the United Kingdom asking the participants to describe how often they performed each type of task. By using the task and activity approach in their factor analysis, Brinkley et al. (2009) were able to form ten groups of tasks. The groups are detailed in Table 1:

Table 1 Task factors with sample items (Brinkley et al. 2009)

Factor	*Sample items*
Data processing and analysis	Compile data; Statistically analyze data; Identify patterns in data/information; Interpret charts/graphs; Enter data
Leadership and development	Make strategic decisions; Develop organisational vision; Identify issues that will affect the long-term future of organisation; Foresee future business/financial opportunities; Manage strategic relationships
Administrative tasks	Manage diaries; Order merchandise; Organize/send out mass mailings; Make and confirm reservations; Sort post
Perceptual & precision tasks	Judge speed of moving objects; Visually identify objects; Judge which of several objects is closer or farther away; Judge distances; Know you location in relation to the environment or know where objects are in relation to you
Work with food, products or merchandise	Clean/wash; Prepare/cook/bake food; Stock shelves with products/merchandise; Gather and remove refuse; Serve food and beverage
People management	Assign people to tasks; Manage people; Teach others; Motivate others; Mentor people in your organisation
Creative tasks	Create artistic objects/works; Use devices that you draw with; Take ideas and turn them into new products; Take photographs; Engage in graphic design
Caring for others	Provide care for others; Dispense medication; Diagnose and treat diseases, illnesses, injuries or mental dysfunctions; Expose self to disease and infections; Administer first aid
Maintenance, moving & repairing	Install objects/equipment; Use tools that perform precise operations; Use hand-powered saws and drills; Test, monitor or calibrate equipment; Take equipment apart or assemble it
Personal, animal and home maintenance	Excavate; Dig; Plant/maintain trees, shrubs, flowers, etc.; Feed/water/groom/bathe/exercise animals; Sew/knit/weave

Next, Brinkley et al. (2009) formed seven clusters of jobs based on the groups of tasks that were most prevalent in them. Finally, the clusters were merged into three categories in the order of how much tacit knowledge was required in the jobs. Their findings suggest a composition of 30-30-40 in the UK economy. The workers of the first category incorporated jobs with high content of tacit knowledge, i.e., leaders and innovators, and experts and analysts; followed by a category comprising of jobs that require some tacit knowledge, that is, information handlers, servers and sellers, and care and welfare workers; and finally the 40% category of jobs that require only little tacit knowledge, i.e., maintenance and logistics, assistants and clerks. Thus, they concluded in their terms that the UK economy comprises of 60% knowledge work jobs, with 30% of that workforce classified as 'core knowledge workers'. (Brinkley et al. 2009.)

Reinhardt, Schmidt, Sloep, and Drachsler (2011) propose a typology for knowledge worker roles and their respective knowledge actions. In their study, they examined and evaluated the extant literature on the definition of knowledge work actions. They also evaluate and extended with additional literature and empirical findings the existing classifications of knowledge work roles. Reinhardt's et al. (2011) study contribute to the literature by proposing a new way of classifying the roles of knowledge workers and the knowledge actions they perform in their day-to-day work. In Table 2, Reinhardt's et al. (2011) typology of knowledge actions is presented with 13 knowledge actions and their respective descriptions.

Table 2 A typology for knowledge actions (adopted from Reinhardt et al., 2011)

Knowledge action	Description
Acquisition	Means gathering of information with the goal of developing skills or project or obtaining an asset.
Analyze	Means examining or thinking about something carefully, in order to understand it.
Authoring	Means the creation of textual and medial content using software system, for example, word processing systems/ presentation software
Co-authoring	Means the collaborative creation of textual and medial content using software applications, for example, word processing systems/ presentation software.
Dissemination	Means spreading information or information objects, often work results.
Expert search	Means the retrieval of an expert to discuss and solve a specific problem.
Feedback	Refers to the assessment of a proposition or an information object.
Information organisation	Is the personal or organisational management of information collection.
Information search	Means looking up information on a specific topic and in a specific form. Often we search using the folder structure of a file system or we search using an information retrieval service.
Learning	Means acquiring new knowledge, skills or understanding during the execution of work or based on formalized learning material.
Monitoring	Means keeping oneself or the organisation up-to date about selected topics, for example, based on different electronic information resources.
Networking	Refers to interacting with other people and organisations to exchange information and develop contacts.
Service search	Refers to the retrieval of specialized web services that offer specific functions, for example, a translation service.

According to Reinhardt et al. (2011), organisations use roles to structure and organise work by describing expected behaviour of individuals within given organisational processes, and they are composed of a vast set of tasks. The use of roles to organise tasks of knowledge worker underlines the different surfaces of knowledge work and underpins the identification of various types of knowledge worker. Table 3 presents Reinhardt's et al. (2011) ten knowledge work roles with short descriptions and typical knowledge actions that they expected to be related to the roles in their study.

Table 3 Typology of knowledge worker roles (adopted from Reinhardt et al., 2011)

Role	Description	Typical knowledge actions (expected)
Controller	People who monitor the organisational performance based on raw information.	Analyze, dissemination, information organisation, monitoring
Helper	People who transfers information to teach others, once they passed a problem.	Authoring, analyze, dissemination, feedback, information search, learning, networking
Learner	People who use information and practices to improve personal skills and competence.	Acquisition, analyze, expert search, information search, learning, service search
Linker	People who associate and mash up information from different sources to generate new information.	Analyze, dissemination, information search, information organisation, networking
Networker	People who create personal or project related connections with people involved in the same kind of work, to share information and support each other.	Analyze, dissemination, expert search, monitoring, networking, service search
Organizer	People who are involved in personal or organisational planning of activities, e.g. to-do lists and scheduling.	Analyze, information organisation, monitoring, networking
Retriever	People who search and collect information on a given topic.	Acquisition, analyze, expert search, information search, information organisation, monitoring
Sharer	People who disseminate information in a community.	Authoring, co-authoring, dissemination, networking
Solver	People who find or provide a way to deal with a problem.	Acquisition, analyze, dissemination, information search, learning, service search
Tracker	People who monitor and react on personal and organisational actions that may become problems.	Analyze, information search, monitoring, networking

Reinhardt's et al. (2011) typologies with their roots in a broad review of literature on knowledge work set a great example on building typologies about the subject. In this study, I use the terms task type and knowledge capability instead of knowledge action, for they can be considered residing conceptually on a higher and lower level of the concept knowledge action.

2.2.1 Manager as one type* of knowledge work job—revisiting Mintzberg and Ropo

OBSERVER: Mr. R.____, we have discussed briefly this organisation and the way it operated. Will you now please tell me what you do?

EXECUTIVE: What I do?

OBSERVER: Yes.

EXECUTIVE: That's not easy.

OBSERVER: Go ahead, anyway.

EXECUTIVE: As president, I am naturally responsible for many things.

OBSERVER: Yes, I realize that. But just what do you do?

EXECUTIVE: Well, I must see that things go all right.

OBSERVER: Can you give me an example?

EXECUTIVE: I must see that our financial position is sound.

OBSERVER: But just what do you do about it?

EXECUTIVE: Now, that is hard to say.

OBSERVER: Let's take another tack. What did you do yesterday?

(Shartle 1956)

The job of a manager is perhaps among the most discussed jobs, partly because of its presence in practically all lines of organisations and industries and the status that often goes with it. The job of a manager exist, because there needs to be people, who are responsible and see that things go as they are supposed to. Of course there are other widely known knowledge work job titles such as a salesman, a lawyer, a consultant, an engineer, an expert, financial advisor, software designer and so forth. However, the job of a manager has probably received the most academic study and hardly any other profession has so many books written about. This probably holds partly thanks to the great popularity of leadership research and books, as the two terms, management and leadership, are inseparable and twined together (see Mintzberg 1973, 2009).

* Other types of knowledge work jobs are,
e.g., salesman, lawyer, stock broker, etc.

Henry Mintzberg (1973) was among the first academic researchers, who took on the task to systematically study the nature of the work of managers and what is that they actually do. He wasn't satisfied with the management definitions of the early 20th century management-thinking pioneers, such as that of Henry Fayol and his five basic managerial functions—planning, organising, coordinating, commanding, and controlling, or that of Luther Gulick whose list included planning, organising, staffing, directing, coordinating, reporting, and budgeting, which later became known as the widely used acronym POSDCORB. (Mintzberg 1973.)

Mintzberg carried out his study on managers by direct observation and having managers write down their activities on diary pads. What he found were extraordinary similarities between managers at different levels of hierarchy. Among these similarities were much work at unrelenting pace, activity characterized by brevity, variety, and fragmentation, preference for live action, and attraction to the verbal media. The job of a manager is characterized by brevity, variety, and fragmentation. (Mintzberg 1973.)

Mintzberg (2009) criticizes the inclination of producing lists of roles and tasks that the managers do. He, however, sees himself as responsible of creating one of these lists shown in Figure 3, although Mintzberg (2009) adds that at least the boxes were connected with arrows to demonstrate relations.

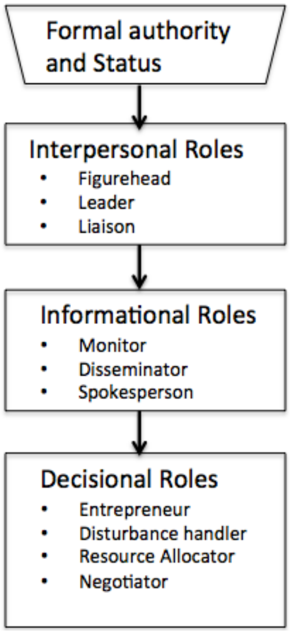

Figure 3 The manager's working roles (Mintzberg 2009)

Decades later in the 1990's, Mintzberg decided to review what more had been studied and written about the work of managers. The answer proved out to be that on the one side there was a lot of information, but on the other side the content did not add up to a theory or a model. Mintzberg then set out to produce a model himself that would satisfy his understanding of the phenomenon we call management. After a dozen efforts over many years, he was able to come up with a model that is presented in Figure 4. (Mintzberg 2009)

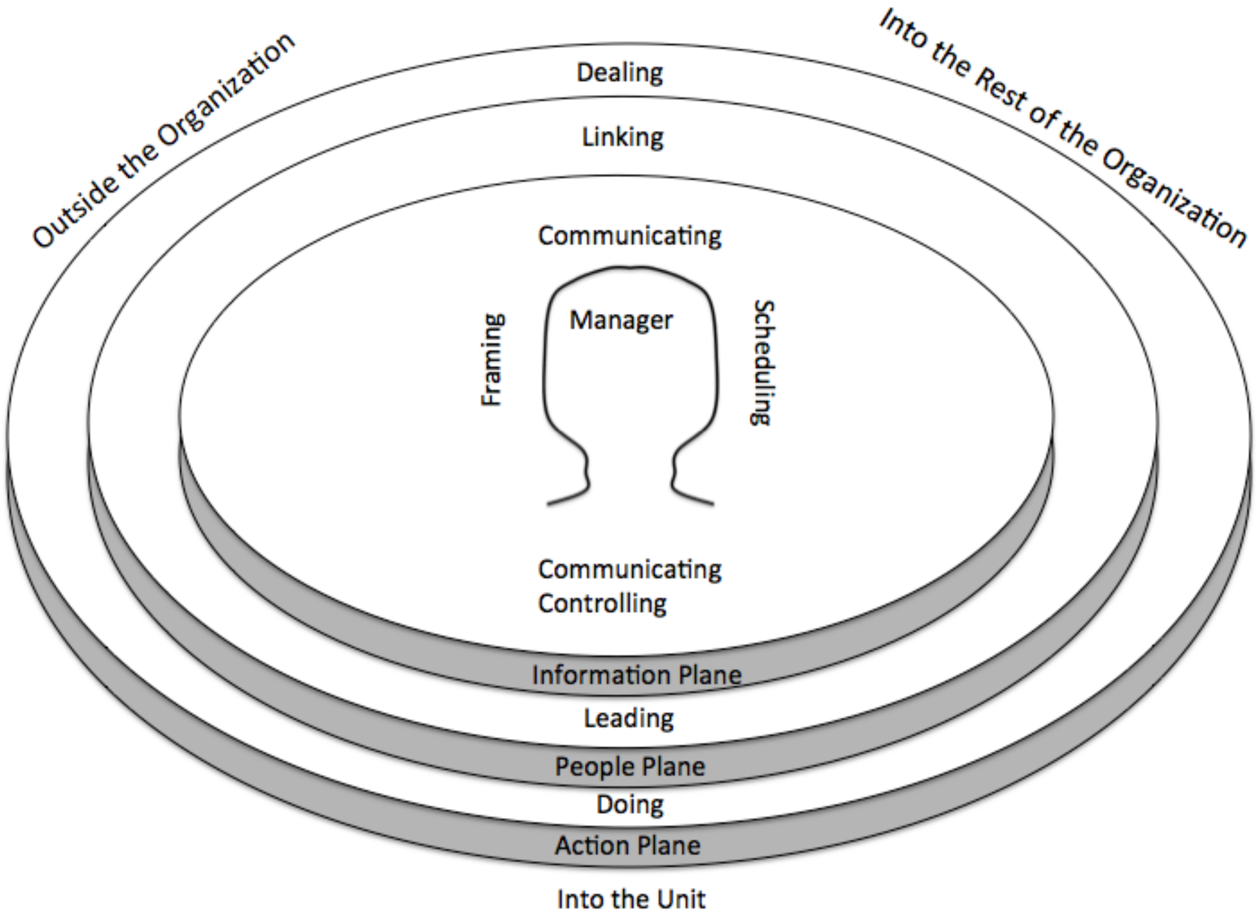

Figure 4 A model of managing (Mintzberg 2009)

Mintzberg's (2009) model depicted in Figure 4 puts the manager in the centre of the unit (or the whole organisation in case of executives) he or she is heading and bearing the responsibility for. A manager takes care of the two external domains of his or her unit. The first is the rest of the organisation, that is, other units and functions of the organisation, in case the manager is not an executive; the second is the outside world of the organisation, which includes customers, partners, and so forth. The main purpose of managing is to make sure that the unit serves its basic purpose. Naturally, each unit, such as sales or research departments, have their own purposes, and there are specialist employees for taking action, but the manager also occasionally joins the action, which could mean, for instance, participating in a negotiation with a customer. However, the manager is usually a step or two back from the level of action. At one level back, he or she inspires and encourages *people* to take action, that is, the manager achieves things through other people by way of coaching, motivating, building teams, strengthening culture, and so forth. Two steps back from the level of action and doing, the manager makes things happen by using information to enable other people to take action. This can mean setting a goal for a team, or information disseminating to staff that he or she has received from a special, external source. Mintzberg (2009) dresses his model nicely in words: managing takes place on three planes, from the conceptual to the concrete: with information, through people, and to action directly. Table 4 lists Mintzberg's (2009) managerial roles and subroles.

Table 4 Roles of managing (adopted from Mintzberg 2009)

<table>
<tr><td></td><td colspan="2">Framing the Job and Scheduling the Work</td></tr>
<tr><td></td><td>Internal</td><td>External</td></tr>
<tr><td rowspan="2">Information plane</td><td colspan="2">Communicating</td></tr>
<tr><td>• Monitoring
• Nerve center</td><td>• Spokesperson
• Nerve center
• Disseminating</td></tr>
<tr><td></td><td>Controlling
• Designing
• Delegating
• Designating
• Distributing
• Deeming</td><td></td></tr>
<tr><td>People plane</td><td>Leading
• Energizing individuals
• Developing individuals
• Building teams
• Strengthening culture</td><td>Linking
• Networking
• Representing
• Convincing/Conveying
• Transmitting
• Buffering</td></tr>
<tr><td>Action plane</td><td>Doing
• Managing projects
• Handling disturbances</td><td>Dealing
• Building coalition
• Mobilizing support</td></tr>
</table>

Mintzberg (2009) divides the roles of managing first into three planes: The informational plane that also includes the manager's self-management, the people plane, and lastly the action plane. He then divides these planes into the internal and external domains, where the internal is into the organisation and the external is either outside the organisation or outside the manager's organisational unit to other units, depending on the manager's position. The internal information plane consists of communication and controlling of the unit under the manager's responsibility. These roles include monitoring, being a nerve centre between members of own unit/organisation, designing, delegating, designating, and distributing. In the external side of the information plane there is communication outside the unit or organisation, which incorporates roles such as spokesperson, being a nerve centre between own unit/organisation and the outside, disseminating, and deeming.

In the internal domain of the people plane the manager's role consists of leading. Leading is composed of energizing individuals, developing individuals, building teams, and strengthening culture. On the external side of the people plane, the manager's role is to link people, which consist of networking, representing, convincing/conveying, transmitting, and buffering.

Lastly, in the action plane the manager's role in the internal domain consists of doing, which covers managing projects and handling disturbances. On the external side, the role is dealing, which incorporates building coalition and mobilizing support among other units or organisations.

To perform tasks a rational agent must have necessary capabilities. However, Mintzberg (2009) chooses to talk about managerial competencies instead of capabilities. The difference between capability and competence is that the former refers to the mere capacity to do something and within this quality there is a potential for development of skills, whereas the latter is the developed type of capability, where the person can do a particular skill or task with efficiency and effectiveness. Competence can cover an integration of knowledge, basic requirements (capabilities), skills, abilities, behaviour, and attitude. Table 5 lays out all the managerial competencies to successfully carry out the roles suggested by Mintzberg (2009).

Table 5 Competencies of managing; adapted from Mintzberg (2004b)

A. Personal Competencies

1. Managing self, internally (reflecting, strategic thinking)
2. Managing self, externally (time, information, stress, career)
3. Scheduling (chunking, prioritizing, agenda setting, juggling, timing)

B. Interpersonal Competencies

1. Leading individuals (selecting, teaching/mentoring/coaching, inspiring, dealing with experts)
2. Leading groups (team building, resolving conflicts/mediating, facilitating processes, running meetings)
3. Leading the organisation/unit (building culture)
4. Administering (organising, resource allocating, delegating, authorizing, systematizing, goal setting, performance appraising)
5. Linking the organisation/unit (networking, representing, collaborating, promoting/lobbying, protecting/buffering)

C. Informational Competencies

1. Communicating verbally (listening, interviewing, speaking/presenting/briefing, writing, information gathering, information disseminating)
2. Communicating nonverbally (seeing [visual literacy], sensing [visceral literacy])
3. Analyzing (data processing, modeling, measuring, evaluating)

D. Actional Competencies

1. Designing (planning, crafting, visioning)
2. Mobilizing (firefighting, project managing, negotiating/dealing, politicking, managing change)

Mintzberg (2004b) groups the competencies into four classes: personal, interpersonal, informational, and actional competencies. The personal competencies pertain to the manager in the centre in the Mintzberg's model of managing. In this domain, besides scheduling his or her time, a manager utilizes his competencies of managing self both internally and externally. In the personal domain, those activities take place that are often associated with the idea of managers thinking of grand thoughts, namely reflection and strategic thinking. The interpersonal competencies are linked to the people plane in the model (although in reversed order with information plane in 4) and include leadership, administration, and networking competencies. Communication and analyzing of information are grouped into informational competencies, and lastly doing, such as designing, project managing, and dealing, is stacked into actional competencies.

Although Mintzberg (2009) does give a comprehensive list of roles and tasks that managers take on and perform and even competencies that managers have, we still are left out with the clear understanding, of what cognitive and physical capabilities are at play in performing these tasks. For example, in the interpersonal competencies class the second competency is leading groups, which includes team building, resolving conflicts/coaching, inspiring, and dealing with experts, the reader is given merely a vague idea what these competencies are. Perhaps, when a manager inspires his or her employees, he is talking to him or her with a certain kind of inspirational voice, using powerful facial and bodily gestures, and choosing inciting and meaningful words and phrases. At the same time, he or she has to understand what motivates people and particularly the person at hand. This requires understanding of the human mind and personality types. Additionally, he or she has to understand the content and the purpose of the task that he or she is trying to persuade and inspire the employee to perform well in order to say things that sound reasonable to the employee's rationale. Opening up the internal workings and processes of the manager's mind and concrete actions would allow us to model parts of the manager's job and reconstruct them digitally to be complemented or performed altogether by computers.

Ropo (1989) studied the behaviour and actions of five bank managers at different levels in organisational hierarchy during the course of organisational change in their respective organisations. Ropo (1989) derived a description along three dimensions from earlier studies at that time:

(1) *Tasks or responsibilities* pertain to individual manager's duties in his or her job in a specific organisational setting, conceived by the manager. These are matters that the manager works on in actuality, or is striving to. They are partly composed of formal roles requirements, but not entirely. The dimension's specific work pertains to purpose or function of the work (Hales, 1988; Kotter, 1982; Mintzberg 1973a), and to demands, choices and constraints (Stewart, 1976). "Managing sales", or "formulating business strategies" serve as examples.

(2) *Goals* pertain to negotiated objectives assigned to a specific job and expressed usually in quantitative and qualitative terms. Particular tasks and responsibilities derive from general goals of work. Examples include "high quality, or "profitability".

(3) *Perspective* of work pertains to the time frame and scope, which the manager finishes that tasks and responsibilities within (Jacobs and Jaques (1987), Kotter, 1982; Lawrence and Lorch, 1967). For example, short can refer to daily concerns, whereas long concerns to future-oriented issues, with time spanning to several years.

As discussed before, competences can also be considered capabilities. In her dissertation, Ropo (1989) used a questionnaire that measures managers' performance along the following list of 19 competences with their descriptions:

1. **Performance emphasis**: the extent to which a leader emphasizes the importance of subordinate performance, tries to improve productivity and efficiency, tries to keep subordinates working up to their capacity, and checks on their performance.
2. **Consideration**: the extent to which a leader is friendly, supportive, and considerate in his or her behaviour toward subordinates and tries to be fair and objective.
3. **Inspiration**: the extent to which a leader stimulates enthusiasm among subordinates for the work of the group and says things to build subordinate confidence in their ability to perform assignments successfully and attain group objective.
4. **Praise-recognition**: the extent to which a leader provides praise and recognition to subordinates with effective performance, shows appreciation for their special efforts and contributions, and makes sure they get credit for their helpful ideas and suggestions.
5. **Structuring reward contingencies**: the extent to which a leader rewards effective subordinate performance with tangible benefits such as a pay increase, promotion, more desirable assignments, a better work schedule, more time of, and so on.
6. **Decision participation**: the extent to which a leader consults with subordinates and otherwise allows them to influence his or her decisions.
7. **Autonomy-delegation**: the extent to which delegates authority and responsibility to subordinates and allows them to determine how to do their Work.
8. **Role clarification**: the extent to which a leader informs subordinates about their duties and responsibilities, specifies the rules and policies that must be observed, and lets subordinates know what is expected of them,

9. **Goal setting**: the extent to which a leader emphasizes the importance of setting specific performance goals for each important aspect of a subordinate's job, measures progress toward the goals, and provides concrete feedback.
10. **Training-coaching**: the extent to which a leader determines training needs for subordinates, and provides any necessary training and coaching.
11. **Information dissemination**: the extent to which a leader keeps subordinates informed about developments that affect their work, including events in other work units or outside the organisation, decisions made by higher management, and progress in meetings with superiors or outsiders.
12. **Problem solving**: the extent to which a leader takes the initiative in proposing solutions to serious work-related problems and acts decisively to deal with such problems when a prompt solution is needed.
13. **Planning**: the extent to which a leader plans how to efficiently organise and schedule the work in advance, plans how to attain work unit objectives, and makes contingency plans for potential problems.
14. **Coordinating**: the extent to which a leader coordinates the work of subordinates, emphasizes the importance of coordination, and encourages subordinates to coordinate their activities.
15. **Work facilitation**: the extent to which a leader obtains for subordinates any necessary supplies, equipment, support services, or other resources, eliminates problems in the work environment, and removes other obstacles that interfere with the work.
16. **Representation**: the extent to which a leader establishes contacts with other groups and important people in the organisation, persuades them to appreciate and support his work unit, and uses his influence with superiors and outsiders to promote and defend the interests of the work-unit.
17. **Interaction facilitation**: the extent to which a leader tries to get subordinates to be friendly with each other, cooperate, share information and ideas, and help each other.
18. **Conflict management**: the extent to which a leader restrains subordinates from fighting and arguing, encourages them to resolve conflicts in a constructive manner, and helps to settle conflicts and disagreements between subordinates.
19. **Criticism-discipline**: the extent to which a leader criticizes or disciplines a subordinate who shows consistently poor performance, violates a rule, or disobeys an

order; disciplinary actions include an official warning, reprimand, suspensions, or dismissal.

As with Mintzberg (1973a, 2009), Ropo's (1989) managerial list of competences are at the level of tasks that the competencies enable performing. What remains concealed, are the innate knowledge capabilities, such as producing natural language or synthesizing knowledge, which lie under these competencies. This is the level of theory that I will address in the next subchapter and in Chapter four, but instead of focusing on managers, which represent only one type of knowledge worker, the level of focus is on knowledge workers in general.

2.3 Knowledge work performance and productivity

More research, reflection and a better definition of knowledge work and knowledge work performance and productivity in the knowledge economy is still needed. The two terms are closely associated with each other, although according to Nicholls (2011) productivity measures the efficiency of production whereas performance is associated with the manner in which someone operates to accomplish something successfully.

According to Drucker (1999) we are now at the same level of understanding knowledge work productivity as we were of manual work productivity in the beginning of 20th century. He goes so far as to say that the single greatest challenge of the 21st century is to get a hold on knowledge work and to increase its productivity. As the proportion of farmers and manufacturing workers represent ever-shrinking shares of the total workforce of developing countries, the increase of the productivity of knowledge workers and service workers becomes paramount (Drucker 1995, see Davis & Naumann 1999).

> *"The chief economic priority for developed countries, therefore, must be to raise the productivity of knowledge and service work. The country that does this first will dominate the twenty-first century economically." (Drucker 1995)*

Drucker (1999) lists six aspects that need to be taken into account in managing knowledge work and knowledge worker productivity:

- Knowledge worker needs to define the task oneself, contrary to a manual worker, who takes the task as given.
- Knowledge worker needs to have autonomy and responsibility of one's own work.
- Continuous innovation needs to be part of the work of the knowledge worker.

- Knowledge worker needs to learn and teach continuously.
- In knowledge work, quality needs to be at least as important as quantity, if not more.
- Organizations need to treat the knowledge worker as an asset rather than a cost to build trust and commitment.

According to Davis & Naumann (1999) there is widespread recognition that productivity varies remarkably not only between individual knowledge workers, but also for the same person in different time periods, despite the fact that it is challenging to measure productivity in knowledge work. Moreover, the scope of satisfactory productivity for knowledge workers is far greater than for labourers who perform physical or clerical tasks. For example, among computer programmers the productivity can be as much as five times higher for the skilful programmer compared to his or her least effective counterpart who, nonetheless, has acceptable programming capabilities. Davis & Naumann (1999) suspect that the productivity differences between knowledge workers may be partly a cause of individual abilities and skills, but also due to individual investment in knowledge work skills, application of knowledge work management principles, and appropriate use of knowledge work information and communication technology.

Davis & Naumann (1999) classify improvements for knowledge work in terms of effectiveness and efficiency (Figure 5). Effectiveness pertains to the quality and utility of knowledge work outputs, whereas efficiency refers to how well knowledge work resources are managed and employed.

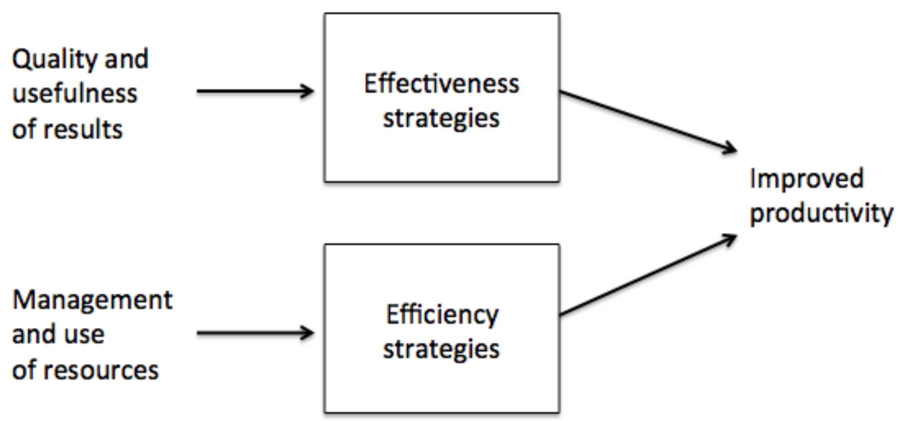

Figure 5 Relationship of Effectiveness and Efficiency Strategies (Davis & Naumann 1999)

In Davis's & Naumann's (1999) terms, effectiveness in knowledge work raises the value of the work outcome. Effectiveness can be enhanced by carrying out knowledge work with more expertise and creativity and also by attaining more complete and timely results. The enhancement brought by information technologies manifests either by (a) widening the scope, depth, and completeness of activities (b) or allowing application of new methods that were formerly unfeasible. Efficiency on the other hand describes the extent to which time and/or effort is properly utilized for the planned task or purpose and can be increased through removing wasteful activities from tasks and introducing technology and tools that remove steps done by the knowledge worker and thus save time. (Davis & Naumann 1999.) Although Davis & Naumann (1999) consider *productivity* as a more general term of creating value through both, efficiency and effectiveness, the term *performance* can be proposed as a more appropriate term for that purpose. In this sense, the term *productivity* refers more to efficiency.

2.4 Models for the mind

In knowledge work, in which processing symbols is in a central role, the human brain is the primary mean of production. Thus, in order to deepen the understanding of the phenomena taking place in knowledge work and to further develop computerized solutions for complementing human performed knowledge work processes or to replace them altogether, it is of utmost importance to have some understanding of the inner workings of the human mind. The field of neuroscience and cognitive psychology offers us useful frameworks for this purpose. Here, I present two models for understanding the human brain and the human mind that I used as intellectual guides for constructing my own framework, which I shall present in Chapter four.

2.4.1 Spaun—A computational neuroscience model for the brain

Neuroscience studies the nervous system, which is the physical foundation of the mind. Attempts in computational neuroscience have created large-scale representations that simulate simple, functioning brains. One such model has been constructed by Eliasmith, Stewart, Choo, Bekolay, DeWolf, Tang, and Rasmussen (2012). A diagram of Spaun, a 2.5 million-neuron computational model of the brain, is presented in Figure 6.

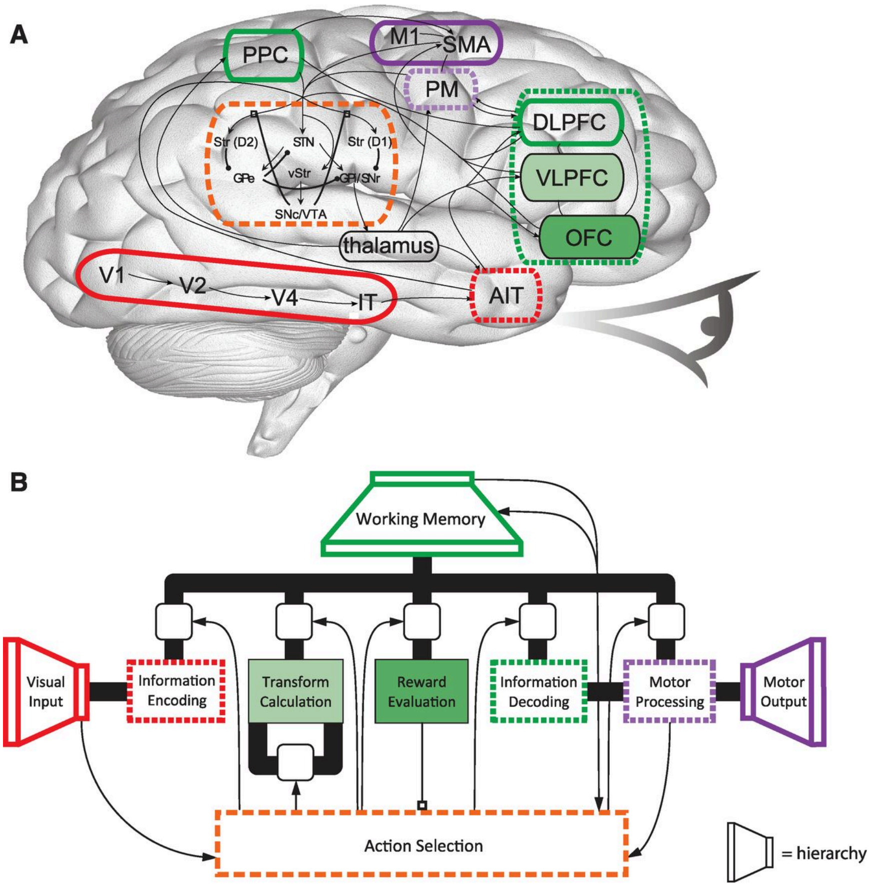

Figure 6 Simplified diagram of Spaun (Eliasmith et al., 2012)

According to Eliasmith et al. (2012), Spaun (Semantic Pointer Architecture Unified Network) responds to the challenge for cognitive and systems neuroscience to relate the incredibly complex behaviour of animals to the equally complex activity of their brains. They claim that the model captures numerous elements of neuroanatomy, and neurophysiology, and psychological behaviour. Figure 6A shows the corresponding physical areas and connections of the human brain, and Figure6B the mental architecture of Spaun. Eliasmith et al. (2012) note that components of Spaun are not task-specific. In other words, they are utilized in a variety of combinations to carry out the selected tasks, leading to the same circuitry being employed across tasks.

Next, I shall present a cognitive model that provides help in creating understanding how the human mind works and performs tasks in the context of knowledge work.

2.4.2 The COGNET framework

According to Zachary, Ryder, and Hicinbothom (1998), the COGNET (COGnitive NETwork of tasks) framework is a theoretically founded collection of tools and techniques for carrying out cognitive task analyses and building models of human-computer interaction in real-time, multi-tasking environments (Zachary, Ryder, Ross, and Weiland, 1992). Cognitive science research forms the foundation for the theoretical underpinnings of COGNET research, especially the branch of symbolic computation, which considers cognitive processes as the working of a particular computational mechanism on a collection of symbols, which are themselves a rendition of sensation, experience, and its abstractions (see, Pylyshyn, 1984; Newell, 1980). According to Zachary et al. (1998), COGNET hence assumes:

- an elementary mechanism of a particular structure with clear fundamentals of operation (cognitive architecture), and
- a collection of elementary symbols on which it works (internal knowledge), and which are arranged in a particular representational scheme (knowledge representation).

Both of the assumptions rely on the studies of Newell (see Newell and Simon, 1972; Card, Moran and Newell, 1983; Newell, 1990), which in its most straightforward layout divides human information processing into three parallel macro-level mechanisms that are perception, cognition, and motor activity—presented as the ovals in Figure 7. Perception—which in COGNET encompasses the physical process of sensation—receives information from the external realm and internalizes it into the symbolic or semantic information storage that both the perceptual and cognitive mechanisms access via an information store, which is used by both. This symbol store is consistent with to what is known as extended working memory (see Ericsson & Kintsch, 1995). Figure 7 depicts this shared store, since both mechanisms share it, but the COGNET architecture has other information store. The cognitive and sensory/perceptual mechanisms include other information stores that both mechanisms access (that is, long-term memory accessed by the cognitive mechanism, and acoustic/visual information stores accessed by the perceptual mechanism.)

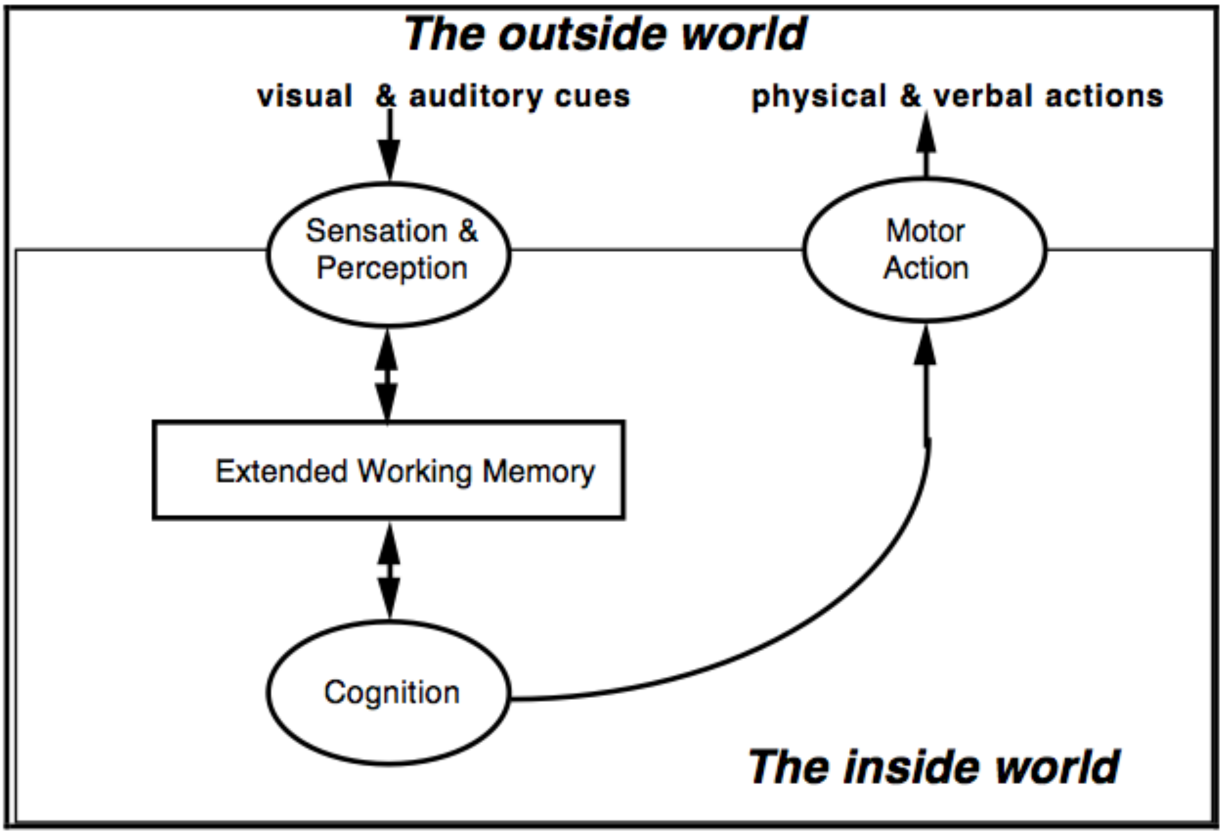

Figure 7 Conceptual view of COGNET cognitive architecture (Zachary et al. 1998)

Zachary et al. (1998) state that using earlier obtained procedural knowledge this internal symbolic representation of the external realm is manipulated by an entirely parallel cognitive process. As a consequence, the cognitive process works on an internal 'mental model' of the world, instead of direct perception of the world. The cognitive process also alters the mental model, as a consequence of cognitive inferring processes (induction, deduction, abduction). Hence, both the perceptual processes and cognitive processes affect the problem representation. In addition to being capable of altering the problem representation, the cognitive process can also call on actions via commands or directions to the motor system. This system functions beyond the range of the problem representation, that is, it lacks access to and is not dependent on the contents of the present extended working memory (Zachary et. al 1998). The motor system allows manipulating physical instrumentalities, which then manipulate the environment (Card, Moran and Newell, 1983).

According to Zachary et al. (1998), COGNET assumes that there exists a specific organisation and representation of internal knowledge, based on the architecture in Figure 7. The person interacts with the external problem realm via the medium of machine system and especially via the person-machine interface. It is presumed that the person is in a work setting, and thus strives to some high-level mission or goal considering the external environment. The activities of the expert human operator of the person-machine system seem as a series of tasks that have complex inter-relationships within this general goal. These tasks represent stacks of knowledge, which the expert has assembled from lower-level course of action and rules to utilize in a large scope of contexts. They are parallel to the different 'case strategies' that form the foundation for the case-based reasoning theory of highly expert decision-making and planning. Some of the tasks are competing for their place in being performed in parallel, whereas others are complementary. Then there are some that have to take place sequentially. Each task represents a particular lower-level goal that the agent could strive for or keep some element of the general mission or goal. (Zachary et al. 1998).

According to Hayes-Roth (1979, 1985) a common declarative representation of the general context and its evolution joins these separate stacks of procedural knowledge or task into a more universal problem solving strategy. This frequent problem representation is exceedingly interactive with any unique task. When a task gets performed, the agent acquires knowledge about the context and includes it into the present problem representation; in the same way, when the problem representation develops, it can adjust the relative priority between tasks and lead one task to come to the surface and demand immediate attention. Coinciding, a lot of the information in the present problem representation is acquired from perceptual processes, such as, by scanning and identifying information from displays, external scenes, or auditory signals, encoding it symbolically, and attaching it onto the declarative problem knowledge. The procedural knowledge in each task encompasses knowledge about when and how to start particular actions at the workstation or in the environment. These action activations are conveyed to the motor system where they are translated into particular motor activity such as pressing a button on a keyboard. This conceptual view of the types and organisation of knowledge is depicted in Figure 8. It gives COGNET the structures required to associate sensation/perception, inferring and decision-making, and action into a collective framework. The conceptual structure shown in Figure 8 was constructed to handle individual-level decision-making. (Zachary et al. 1998).

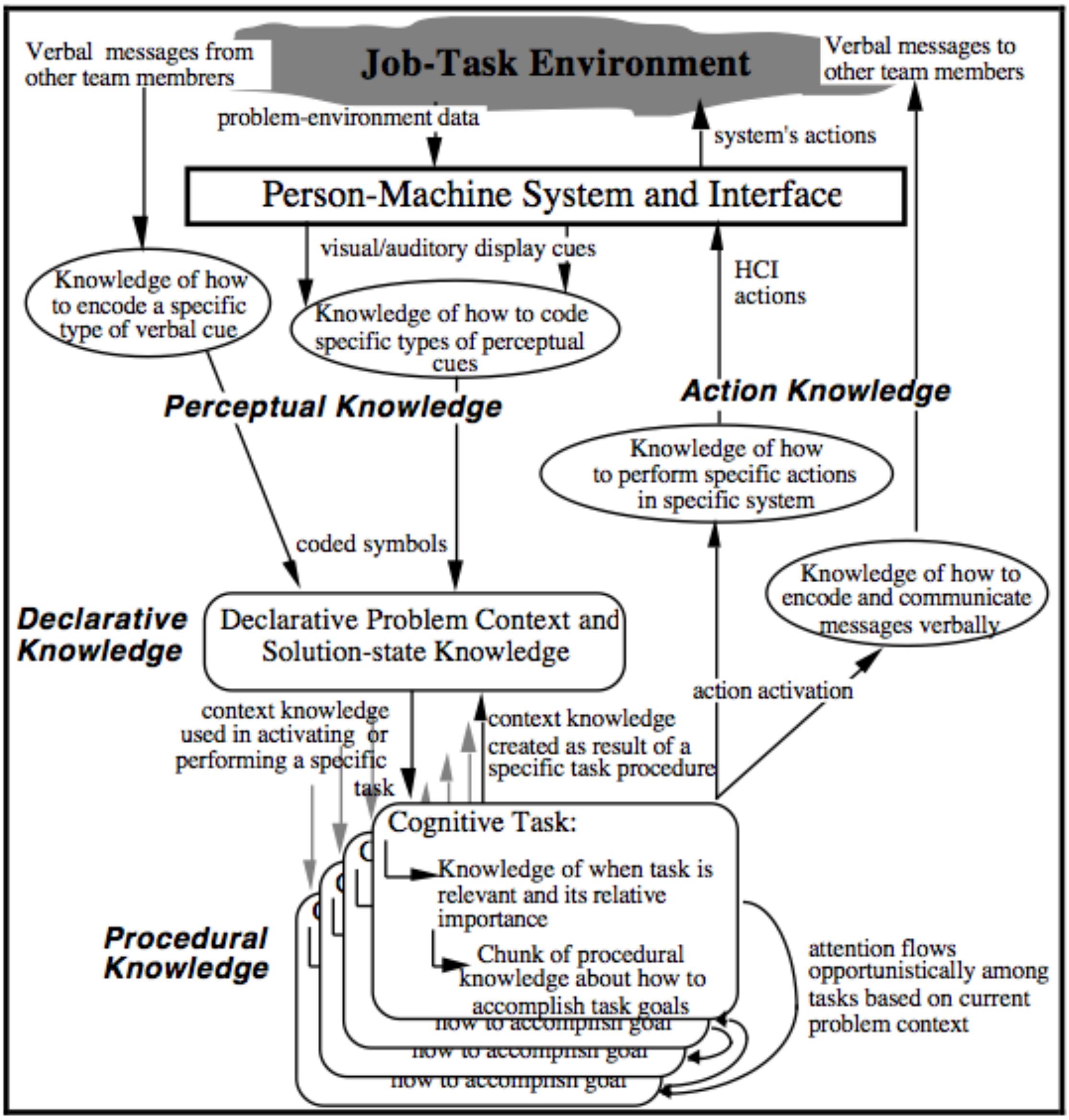

Figure 8 COGNET knowledge framework (Zachary et al. 1998)

According to Zachary et al. (1998) among the primary purposes for developing a theoretical framework for human information processing and decision-making is that the framework can provide a way of breaking down empirical phenomena in a manner that allows their more orderly description. The process of constructing a formal description for a specific series of human activities in a specific domain composes a structure of that central component of human elements, the task analysis. Specifically, it is a cognitive form of task analysis, since it links cognitive constructs and workings to the perceived behaviours. In order to carry out a cognitive task analysis (with COGNET or similar frameworks), it is required to have a series of constructs that are to be identified and depicted, and symbols with which to depict them. The knowledge framework described above in Figure 8 identifies the series of constructs that are required for real-time, multi-tasking execution. (Zachary et al. 1998).

2.5 Summary of theory and its connection to this study

Based on the theoretical discussion earlier, it can be stated that the two concepts, knowledge and information, can, and should be conceptually separated (see Wilson 2002). Information is something that a knowledgeable agent can process and link to former knowledge, whereas knowledge provides the means to interpret, process, and produce information. Knowledge also comes in many forms in respect of tacitness. Explicit knowledge is knowledge that a great proportion of people share, whereas tacit knowledge is something that is known to fewer sometimes only to the person him or herself or at times even beyond one's own awareness in the case of ineffible knowledge. The level of tacitness tells how unattainable and incommunicable that knowledge is to other knowledgeable agents such as people or computers. (Grant et al. 2007)

As there is now something to hold on in terms of knowledge and information, one can move on to knowledge work, where the two are put to productive use. Knowledge workers are people with jobs, in which the roles and tasks involve mostly information processing and where language is a central tool as it enables communication. In order to be able to perform knowledge work tasks, certain capabilities are required. Such capabilities include, e.g., understanding and producing natural language, which are used in absorbing and disseminating information from and to people orally or in written text.

The two terms *knowledge work performance* and *knowledge work productivity* are closely related, albeit the former can be considered having a more general meaning. Knowledge work productivity can be considered of being composed of efficiency and effectiveness. Information technology has contributed to the productivity of knowledge work by either complementing knowledge work tasks or replacing humans in them. The latter can be achieved by programming computer systems with capabilities to perform certain knowledge processes that then take the place of humans in knowledge work tasks. The development of information technologies has enabled knowledge workers to save time and increase the quality of their output.

Cognitive psychology and neuroscience, among other mind sciences, have provided us with models for the mind. Understanding the workings of the human mind enables understanding how knowledge work is performed. A central idea of the COGNET framework and the Spaun model is that the mind takes in information from the environment, processes it using knowledge and various cognitive capabilities, and communicates information and generates action in order to have an impact on the environment for the purpose of achieving goals.

3 DESCRIPTIONS OF KNOWLEDGE WORK JOBS

I interviewed a total of five knowledge workers for this study. Industries in which these knowledge workers and managers were employed were varying to attain a more general perspective in hope of finding some universal tasks and required knowledge capabilities that are shared by knowledge workers. I present each knowledge worker job in their respective subchapter. I begin each subchapter by presenting the employing organisation and the knowledge worker's place in the organisation. I then move on to describe the roles the knowledge worker has in the job and finally sum up by summarizing key points.

3.1 Amadeus at a multinational IT company, Trendster

3.1.1 Organization

Amadeus (fictional name) works at a multinational Internet business company, Trendster (fictional name). Amadeus's job title is user operations associate and he works at Trendster's Customer operations office, also the headquarters for all regions except American operations. Figure 9 presents the simplified organisational chart of Trendster.

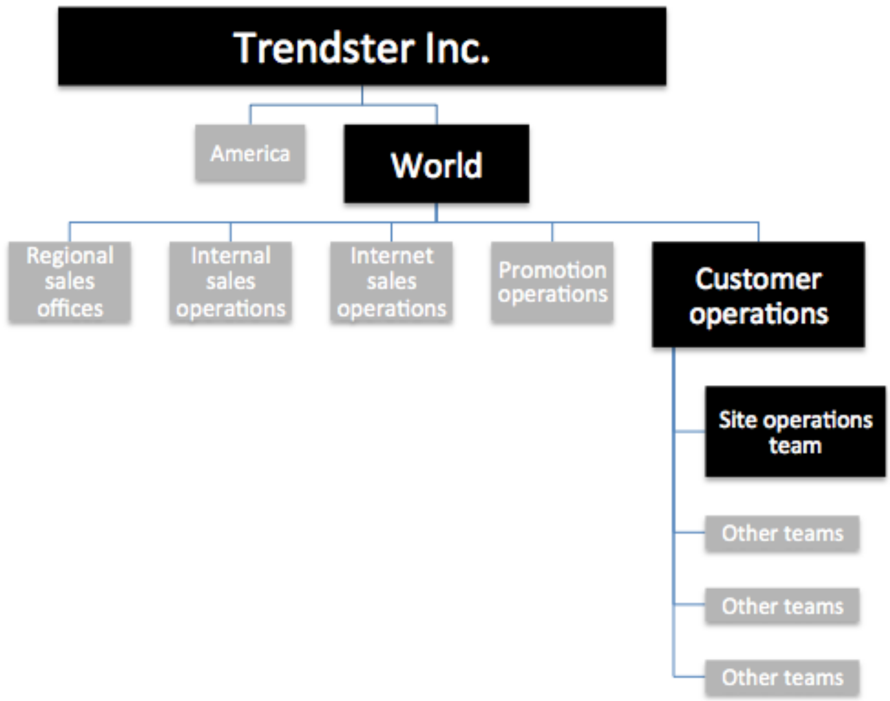

Figure 9 Simplified organisational chart of Trendster Inc.

All Trendster's operative functions are allocated in a major European capital city, Berholm (fictional name). In addition, the company has direct sales offices in many countries. Besides Customer operations, the Berholm unit is home to Internet sales operations unit that is responsible for middle-sized advertisers, Internal sales operations unit that contacts *'cold calls'* to new middle-sized customers, and lastly Promotion operations, which handles the operations of major customers. The Berholm unit employs several hundred people.

3.1.2 Roles and tasks

Amadeus's job is divided roughly into two major parts consisting of roles. In the first part it his roles consist of monitoring and managing the user experience of tens of thousands of Finnish Trendster users. The second part is being a member of Site operations team, which is an internal support team for commercial brands that have a company page in Trendster.

Role 1: Developer of the automated user self-service system

The first part of Amadeus' job is to make sure that the user experience of thousands of Finnish online users of Trendster is as smooth as possible. One role in this is managing user support. Because of the sheer number of users, it is no way possible to help every user individually via phone or e-mail. Hence the support is mostly built into the company's intelligent systems and self-service. The ultimate goal is to make the intelligent systems and online self-service so sophisticated that it removes the need for the user to ever contact a real person at Trendster. Amadeus's role is also to think of ways in which the automated user self-service system could be developed.

The role involves searching for background information, testing the system, and brainstorming with co-workers. Trendster has complex internal tools developed for improving automation, which has taken a lot of time and effort to learn for Amadeus, who has an educational background in business studies instead of computer science. He reckons that the most important employee skill in using the internal automation tools is pattern recognition. When Amadeus notices some routine repeating and recognizes some pattern in it, he uses a statistics program to verify the hypothesis. An example where this is being used is automatically preventing different sort of disturbing user behaviour in Trendster or even automatically removing the user altogether. Pattern recognition, mathematical insightfulness, general technical know-how and both expertise and creativity in using the tools are all traits that are highly beneficial for this task. Some parts of the role also require programming skills. Amadeus thinks that the automation task is perhaps the most challenging part in his work and feels at times that it surpasses his competence.

Role 2: Localization person

Another task associated with user experience is localization, in which Amadeus ensures that help centres and the contents of Trendster's web page work properly in Finland. Examples of these are certain security functions. If a user loses one's password, it results in locking up the account. Reopening the account is done with backup-mechanisms. One of Amadeus's tasks is to check that the Finnish translations are grammatically correct and to think how the backup mechanisms and translations could be improved.

Role 3: Member of Site operations team

One of Amadeus's roles is to be a member of Site operations team. The team's function is to support Trendster's sales teams with their major customers that consist of large multinational brands that have their own company pages in Trendster. Amadeus' role in the team involves troubleshooting and providing answers to the sales teams' technical questions.

Amadeus estimates that both the aforementioned job functions, i.e., managing the user experience of Finnish users and being a team member of the Site operations team total approximately 40% of his total time.

Role 4: Direct user support person for Finnish users and companies

In some cases, Trendster's intelligent systems cannot provide an automated solution to a user or company problem. In these cases the user contacts Trendster directly. Amadeus's role is to handle the Finnish user support cases. One such situation is when a user dies. In such occasions, close relatives will have to send relevant documents to Trendster. Next Amadeus will verify that all the required documents are received and authentic. This demands locational knowledge and interpretation of how, e.g., Finnish death certificate looks like and how to deal with Finnish government officials.

Another situation, where Amadeus's personal assistance is needed, is when a Finnish company, e.g., restaurant wants to reserve an official place in Trendster and control it. In such occasions the restaurant has to convey certain official documents to verify its identity, such as bills. Amadeus evaluates the validity of the documents, which he sees as quite routine work, but being still important for Trendster, because different countries have different customs and documents and thus need local knowledge and human consideration.

In these tasks, the context usually reveals a great deal of the user's problem. The title already often discloses much of the issue. As presumably in the vast majority of large firms, in most cases the answers are readily written at Trendster, that is to say, no one is writing them each time individually. Amadeus has developed a routine of recognizing the nature of the problem only from a couple of sentences. In the beginning, however, Amadeus struggled each time in figuring out, what the user wanted, especially if the user accidentally used wrong technical terms about various elements of the service.

Amadeus outlines that if a user ever needs to contact Trendster, it is an indication of failure in some of the automated processes. For example, if a user account is mistakenly removed from Trendster, it is usually caused by the automation system—rarely by an employee.

Role 5: Contact person

In case there is a situational escalation with a user or a customer company, Amadeus is the contact person between Trendster and the user or the customer company. This includes using an internal delegating system that is at Amadeus's area of care.

Role 6: Job applicant evaluator

Amadeus is a member of the recruiting team, where his task is to evaluate the suitability of job applicants for different positions.

Overview

Amadeus's job as a user operations associate involves six roles altogether. Some roles, such as localization person and direct user support person for Finnish users and companies are more routine-like in nature, whereas the developer of automated user self-service system role, for instance, calls for more creativity and problem solving. Table 6 presents the roles of Amadeus's job as a user operations associate.

Table 6 The roles of Amadeus's job as a user operations associate

Job	Roles
User operations associate	Developer of the automated user self-service system
	Localization person
	Member of Site operations team
	Direct user support person for Finnish users and companies
	Contact person
	Job applicant evaluator

Amadeus points out that although all employees are officially appointed to definite tasks, in reality the areas of responsibility are alive and changing. The work is a mix of routine tasks that a computer would be able to do probably in a matter of two years. Other tasks, however, are of nature that a computer couldn't currently handle, such as verifying a Finnish death certificate, but that a machine might be able quite possibly to do even in the near future. However, parts of Amadeus's job can be considered developmental, which he sees as difficult or even impossible to automate. In these tasks, people are summoned from different functions of the Berholm unit and they are assigned to discuss and generate ideas on how the service could be improved, or pertaining to that, testing on how various things in the service appear to the user.

3.2 Arnold at a Finnish oil procuring company, North European Oil Trading Ltd.

3.2.1. Organization

Arnold (fictional name) works at North European Oil Trading Ltd. (NEOT). NEOT is a Finnish oil product wholesaler and employs 54 workers in oil and logistics industries. NEOT's customers are St1, ABC gas station chain and St1 Energy, which practically means Shell gas stations. In heating oil sales NEOT's customers are St1's direct sales, SOK's heating oil sellers and Finnish agricultural trade company Hankkija-Maatalous Oy. NEOT's mission is to purchase fuels for its customer-owners and transport them, at the same time creating as much of relative competitive edge as possible by carrying them out efficiently. Figure 10 presents NEOT's organisational chart.

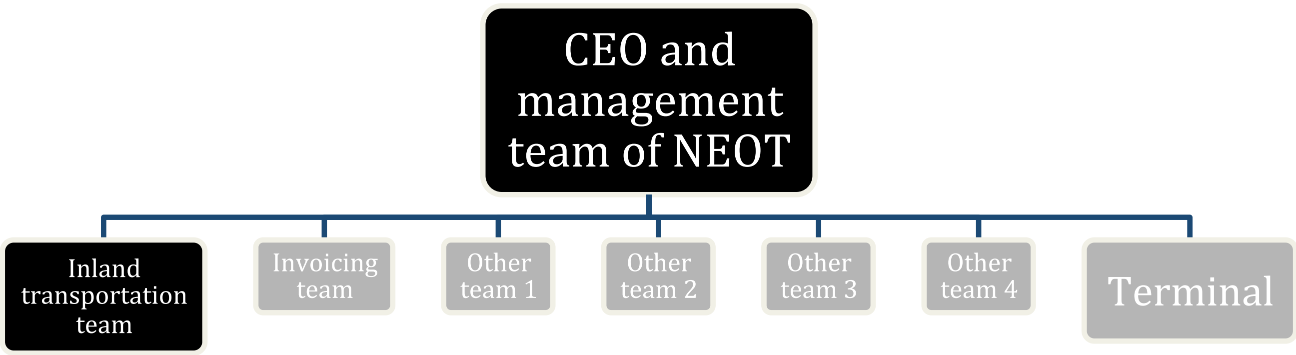

Figure 10 Simplified organisational chart of NEOT

NEOT has an office in Helsinki city centre, Kamppi, which employs 20 people. The rest work at terminals. At the terminals, there is a terminal manager and workers, who handle the practical functions required to run the terminals. For example, they perform operations related to receiving a ship. There are also some office workers at the terminals, but nearly all the knowledge work is centred in the office at Kamppi, Helsinki. The organisation structure has two layers: the management team headed by the CEO and six other teams besides the terminal unit. One of the six teams is the Inland transportation team, where Arnold is positioned along with three other employees.

Business processes

NEOT has two primary processes—invoicing process and logistics process. The Inland transportation team, where Arnold works, has the responsibility of managing fuel transportation from NEOT's inventories to the customer. Destinations can be gas stations and heating oil customers. The logistics process starts from an order and ends, when it's been invoiced. The whole process is composed of a multitude of phases, like managing hauling, and are all tightly integral to the business processes of the whole company. At the moment, the transportation service is outsourced completely to 13 different transport firms. NEOT pays them freight compensation in cents per litre.

Biggest challenge of the unit

Arnold sees that the company's performance is measured by its ability to deliver products to customers at any given price. Conducting purchasing is the main challenge of the whole business. That is where the money is made, he states. There are also challenges pertaining to the company's strategy and future trajectory that have to do with the fact that NEOT has grown rapidly. On the one hand NEOT's success depends on its ability to react and change, and on the other hand its capacity to exploit economies of scale, Arnold explicates. At the organisational level, Arnold recognizes that leadership and communication are the main challenges.

Another challenge is that the data in NEOT's databases is very hard to manage. The data is not in the right form and it takes a lot of time and effort to dig it out and to compile it to useful information. One of the company's clear goals is to get the data into a form that turns into useful information with a click of a button, after which one can make a report out of it or even that the report comes out ready. Such was the case in a company in Holland, where Arnold and his co-workers saw an employee getting a complete report into a spread sheet program with a single click of a mouse.

One of NEOT's most important goals is to thoroughly automate manual and routine knowledge work, which they are trying to tackle with an IT project. As an example, where this is attempted, is in reconciliation. In reconciliation a container truck goes to a terminal and loads a cargo of gasoline to the truck and unloads, e.g., 5000 litres at a gas station. In the next step, the driver writes up to a consignment note with a pen that 5000 litres has been delivered. At a certain point an employee at an office receives the consignment note and types into NEOT's ERP system the hand-written figure. Some 20 employees in Finland are doing this task. NEOT sees this as futile. In Arnold's words, "It is like knowledge work Taylorism at its worst."

3.2.2 Roles and tasks

Arnold's title is project manager and his responsibilities are roughly divided into two areas of responsibility. Firstly, Arnold is planning and preparing a project, whose purpose is to resign the whole function of the Inland Transportation team in the smartest possible way. Secondly, Arnold is a project manager in an IT project, which is currently under way. Arnold's days are so varying that it is difficult to draw any estimations on what proportion of time each of his roles consumes.

Role 1: Planner and organiser of tender preparation

The primary reason for redesigning the function of the Inland transportation team is that at the time of writing this NEOT is about to publicly ask for bids for transportation, as its contracts with the transportation firms are to expire in 2013. Arnold's role is to plan and organise the whole project of preparing the tender for the transportation firms. Putting out a tender for the firms requires gathering relevant information to work out stipulations for the tender document, sending the documents to the firms, and gathering the bids. A key source of information for the planning is the company's enterprise planning system, which consists of data and information associated with transportation, such as old transportation contracts and freight prices.

Role 2: Industry investigator

Redesigning the team's function is also linked to an investigation on the fuel industry that Arnold is simultaneously conducting. In order to carry out the investigation, Arnold interviews various managers in the Finnish fuel industry to gather information about the developments on the horizon. He then uses these forecasts as an aid to design the future function of the Inland transportation team. Besides industry experts, Arnold gathers information from his team's supervisor, who has built expertise and knowledge during years of experience.

Arnold uses the information for planning and preparing the team's development project. In the beginning there is a huge amount of data and information that he collects, puts into a structured form, and formulates concrete alternatives that his team presents to NEOT's management team. Arnold finds it in many ways similar to doing research, such as a master's thesis. They even have research questions.

Role 3: Member of development workshops

An integral part of the team redesigning project are workshops, whose purpose is to think of optimal ways to conduct the transportations, evaluate how they would affect their business line, learn about the collaborators' perspective, and gain insight what would be the best way to serve the customers. Among the primary goals is to optimize the whole system so that it would enable NEOT's customers to release capital. It pertains to managing inventories, which influence current assets, which in turn relate to the balance sheet, which affects financing that finally is the major factor in investment decisions.

The workshops usually begin with a PowerPoint presentation by one of NEOT's managers or its collaborators. When a NEOT manager holds a presentation, it is usually Arnold's task to prepare the presentation for him or her. The workshops are to a great extent composed of explaining what Arnold's team has done and what the team is about to do next. Both parties will then ask each other questions on what they see would be the optimal way to operate. Arnold sees the whole process composed of informing and explaining the story of NEOT, but also gathering ideas to create new knowledge. Perhaps the most important thing in the workshops, in his view, is to get a validation from the other party on NEOT's policies, that is to say, to make sure the company is on the right track. If there is a common understanding between the parties, it accounts a validation.

Role 4: Data and operations analyst

Arnold has recognized that looking at data in NEOT's databases and gaining insights from them is among the most important knowledge work tasks he is involved in. It has to do with the total performance levels of the transportation firms. His task is to recognize improvement potential and come up with ways of attaining them. An example would be price levels, where Arnold sees a price of an oil product at one place and then another price in another place and finds, for instance, a potential increase in margin. As another example, by looking at the data in one of NEOT's systems, he sees how often fuel has been brought to a gas station and at the same time discerns how the fuel surface height of the gas station's fuel container varies. He knows what is the optimal situation and by looking at the data, he can spot if it's not optimal.

To accomplish this, Arnold goes to different systems and collects data from them and looks at the numbers from different locations. Out of those numbers he does a calculation.

Role 5: Manager of the IT project system specifications

Arnold has been assigned as the project manager of NEOT's IT project. Besides coordinating the project, his role is to participate in determining the specifications for the software. The goal of the project is to create an extranet-based system that has four functionalities that are reclamation handling system, fuel order system, winter quality alteration system, and terminal reservation system. The extranet system will allow NEOT and its customers and suppliers to share information more efficiently. As an example, formerly NEOT's reclamations and failure notifications were received and handled via e-mail or phone. With the new IT system they are all gathered into one place, where they can be managed more efficiently. In a way, all e-mails (of this type) are now moved to one place. The specification process involves meetings with the software company, which NEOT buys the programming for the software from. In the meetings the members discuss the specifications and their feasibility and decides on the final form of the software.

Role 6: IT project coordinator

As Arnold is the manager of the IT project, it is his role to also coordinate the project. It relies heavily on communication between project members via e-mail. Arnold's coordinator role requires gathering information about the work of the project members to make schedules, keeping members up to date and delegating tasks. He also contacts people in Holland to get information on the execution of the program, as they already have the same system in use.

Overview

Arnold's job as a project manager involves six roles. His job doesn't involve any routine operational processes, thus his job is completely developmental in nature. Table 7 presents Arnold's roles.

Table 7 The roles of Arnold's job as a project manager

Job	Roles
Project manager	Planner and organiser of tender preparation
	Industry investigator
	Member of development workshops
	Data and operations analyst
	Manager of the IT project system specifications
	IT project coordinator

Arnold stresses that the content of his job is highly varying. On some days, he can spend the whole day at office analyzing data or sitting at workshops. On other days, all the time goes by interviewing industry experts at their offices. Arnold finds that a challenging part in being a project manager is that there are rarely clear barometers on how well things are advancing, which makes uncertainty a constant companion. On the other hand, the rewarding part of the job is that it is intellectually challenging and one gets to fully put one's rationality and creativity in use.

3.3 Barney at Metso Corporation

3.3.1 Organization

Barney (fictional name), an engineer by his educational background, works for Metso Corporation, a multinational company of some 30 000 employees and a supplier of technology and machinery in the process industries including mining, construction, pulp and paper, power, and oil and gas. More specifically, he works at a factory of Metso Mining and Construction, a division of Metso Corporation in Finland. The factory employs some 1000 people. In the factory there are assembly workers, engineers, and some corporate governance. Figure 11 presents Metso's organisational chart.

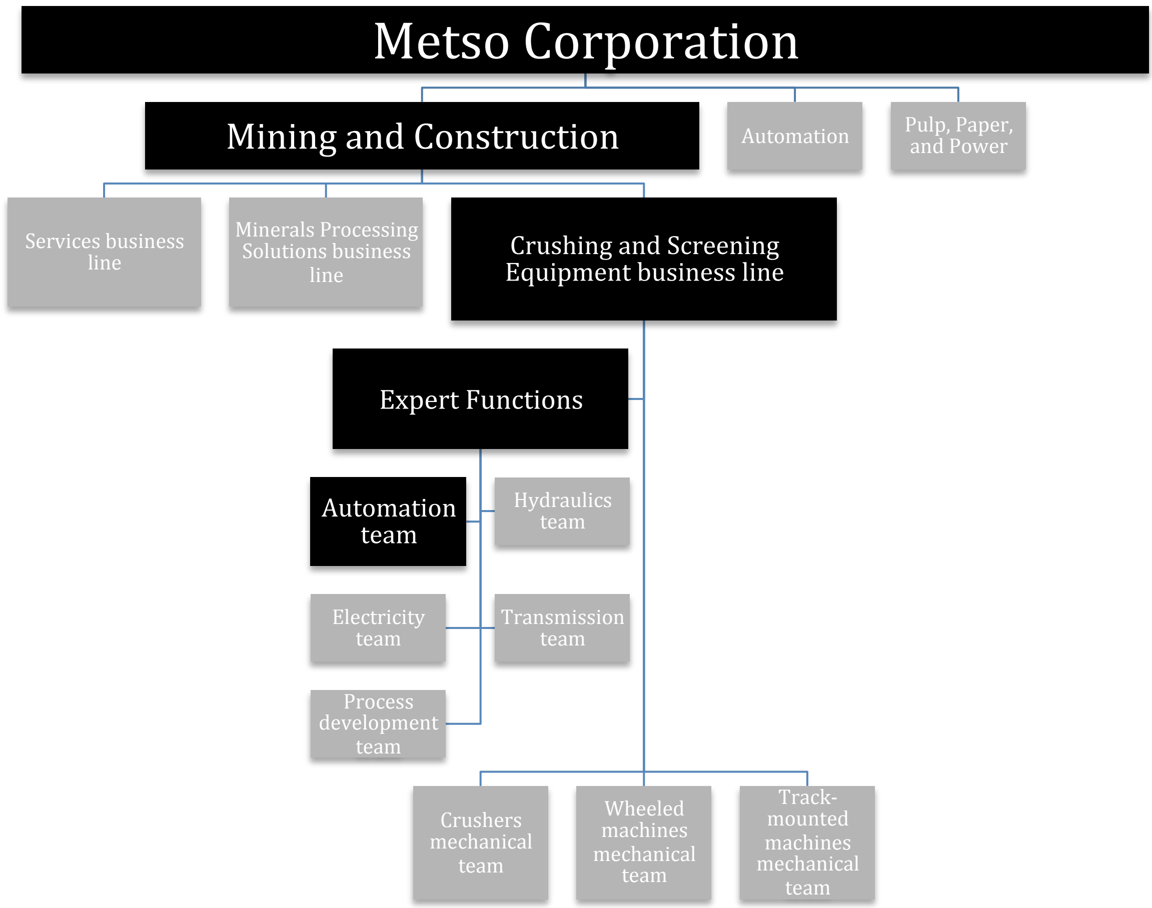

Figure 11 Simplified organisational chart of Metso Inc.

In the factory, Barney works at the Crushing and Screening business line, which designs and builds track-mounted machines and crushers. He works in the automation team, a band of seven, which is part of the Expert Functions. The Expert Functions is a support function that consists of five expert teams, which are automation team, hydraulics team, electricity team, transmission team, and process development team, each of which has its own supervisor. Altogether the function employs around 50 workers. There are also individual employees in the Expert Functions, who don't belong into any teams, such as industrial designers and security inspectors. At the factory there are four organisation levels, in which Barney is in the lowest.

Business processes

The Expert Functions serves the engineering of various machine types. Mechanical engineering teams design the actual physical parts of the machine, after which the expert teams then design the various supporting machine functions, such as hydraulics, which is designed by the hydraulics team. Each mechanical engineering team is specialized in certain types of machines, such as wheeled or track-mounted machines, but the Expert Functions consists of teams that are specialized in these different functional areas of the machines that all machine types have. Barney's automation team is one of these teams. For instance, when a mechanical team of crushers has designed the mechanics for a new crusher, it needs Barney's automation team to design automation for the machine and correspondingly the hydraulics team to design the hydraulics.

Besides the team leader, Barney's automation team has six automation engineers and a documentation specialist. The team's mission statement says, "We apply automation to machines". The automation engineers have different roles. Barney is responsible for certain diesel-systems in track-mounted mobile machines. His colleague is responsible for mobile machines, but different type of intelligent controllers (ICs). Another part of the team designs stationary machines, unit crushers. Then there's one engineer who deals with both. Lastly, there is an engineer, who focuses on the upper level systems, such as remote controlling and remote monitoring, and control systems of the whole process. Different engineering departments sit in different sections of the office. The teams sit physically together in the same section of an open office, except the team leaders, who sit in separate glass rooms. The whole engineering department, where Barney works, has around 150 people working in different teams.

The automation team cooperates a lot with the other expert teams, namely the electricity team. Moreover, in cases where there is trouble with automation, the team's role is to support production, which installs machines, and maintenance, which operates in the field maintaining machines. After having received specifications from other teams, the automation team then thinks how they're going to put it into practice.

After designing the automation systems, they have to be programmed. The automation team buys programming services from subcontractors. They use four different programming service providers that have team's serving only Metso's automation team. The reason for using many subcontractors is to disperse in order to avoid becoming dependent on any single supplier. On the other hand, when Metso wants to test the software, it uses different subcontractor as to gain an objective view and thus avoid disputes, if problems occur.

The automation team receives information mostly from the product management organisation, which practically decides, what the automation team does. The product management organisation has product managers, product engineers, technical support, and technical specialists. In the end, it is the product managers, who decide what features will be in the machines, which determines what the automation team does. First, the product managers tell what they need, and if they, e.g., want to change hydraulics, they then inform the hydraulics team on what sort of hydraulics is needed, which in turn informs the automation team on what sort of controlling system is needed for that kind of hydraulics.

The biggest challenge of the unit

Barney sees that the greatest challenge of his team and business line is the flow of information. For example, a mechanical engineer fails to inform the right person that he changed a transmission device and it now needs another controlling system. As a result, a machine stands non-functional on the yard, because nobody was told that it needed new controlling software. In one such case, the machine got to the test phase until Barney received a call that the machine was not functioning.

Besides information flow, he sees that attitude plays almost an equal part:

“Nobody gives a damn about anything. It is really a terrible place. Very few actually care about the things. They just work there and don’t care. I don’t care that much either. You adjust pretty quickly to the habits of the house.”

Barney sees the attitude problem to be especially production’s problem. Although they do work and produce, they don’t care much if schedules fail and also show indifference in other ways.

3.3.2 Roles and tasks

Barney’s title is automation engineer. In the automation team, his role is to design automation to track-mounted machines. At Metso, they have a table, where employees are supposed to evaluate what tasks they spend their time in.

Role 1: Designer of automation specifications

The core of Barney’s work is to design automation system specifications based on the requirement specifications received from the product management organisation or the other expert teams. He thinks of ways how to make the automation system and how will the system fit to the existing systems. The final product is a documentation, on which Barney bases his bids that he requests from programming subcontractors. The specification documents are written in plain English so that even laymen can read them. He estimates that this role takes some 10% of his time. Barney also finds it the most challenging and skill demanding, but also likes it the most about his job.

The work is mostly incremental, that is, they change the systems only a little to keep them uniform, because the automation systems have to be compatible backwards. Barney writes documents based on the systems that the programmer then uses to write the program. In case there’s more to do, it involves project management, which includes scheduling and decisions over, who does, when and where.

Barney calls for bids against his specification document from subcontractors and buys programming from whoever can offer the best deal. After that, he approves the offer with his boss, who is officially responsible for the decision, but in practice the boss knows very little about the details and often bases his decision on Barney’s evaluation. Usually their price evaluation is on the low end. After time, Barney has developed a conception about how much time a piece of work takes. He anchors his estimation about the work’s value in his experience. Price isn't the only factor. It matters also, who has done the kind of work before. Even though Metso tries to avoid commitment to subcontractors, it happens inevitably.

Defining specifications is precise work, because the blocks of software have to fit many places. This is where Barney is supposed to do cooperation with the other mobile automation engineer in his team, in which they check that the software will become compatible.

In other words, Barney writes a document to the program designer that specifies what the software needs to be like. Barney designs the automation system, which is then turned in to software design and the programmer programs it accordingly. He is the link between what machine should do and the programmer. The document is not written in pseudo-code, but in plain English so as to make it more understandable by the whole organisation, such as maintenance.

Role 2: Requirement specifications informant

Another 10% of Barney's time goes by gathering information from meetings, where the requirement specifications are discussed and defined with other engineers. The meetings have representatives from different departments and teams. Normally there are participants from hydraulics, electricity, and mechanical teams and a project manager from product management organisation. One meeting typically has 7 to 8 people and the people are usually the same every time, although it varies sometimes depending on the type of machine that they design.

Meetings are important source of information, but even more important are face-to-face discussion with the relevant engineers after the meetings. The discussions typically take place at engineers' desk and involve looking at, e.g., hydraulics or electricity pictures on screen or on paper. Whereas general things are settled in the meetings, the more specific details are discussed and agreed on between two people. This is because the more specific details are not relevant to all 7 or 8 participants in the meetings.

Barney dislikes that he needs to sit and listen to things that are irrelevant to him in the meetings. Only when the discussion moves to automation issues does it become relevant to him. Barney estimates that on general 25% of the time in meetings is relevant and 75% serve no purpose to him.

Role 3: Support person for programmers

If Barney has done a poor job in specifying the automation system, and the programmer fails to understand some specification in the document, the programmer then has to ask Barney what he has meant by the specification. Sometimes he even himself doesn't remember what he has thought the program should do, but he, nevertheless, develops some answer. What makes the task even more challenging is that the programmers' questions are often poorly defined, which results in that it takes more time to come up with a good answer. The problems that Barney deals with the programmers often have to do with issues, where a specification is not doable or that some specification requires changing another thing at the same time. In this task communication is done via e-mail or phone. Barney finds that e-mail's advantage is that the communication leaves a record and the messages can be shared with others, whereas phone call is better for getting the point across.

Role 4: Technical support person

Technical support takes about a day out of Barney's week or 20% of his time and it is an on-going part of his job. It is usually phone calls from different parts of the world, where maintenance support or a maintenance man at the field asks for advice. Technical support includes also calls from production. The production calls up Barney, if they have some problem that other engineers haven't been able to solve and the problem has to do with automation. In some cases he goes over to the production area in the factory and tries to come up with a solution.

Role 5: Automation software tester

When a new piece of automation software is ready, it needs to be tested to make sure it works correctly. Testing is a role that Barney does only in certain weeks, depending on the phase of the project. When there is testing, he does it for a week and after that, there's no need for it in weeks. It takes around 20% of his time.

The testing is conducted with a simulator, where the user takes the role of the machine. It simulates all the sensors and functionalities of the machine, such as pressure indicators and limit switches. The user controls the simulator by turning on and off switches and at the same time monitors that the program does what it is supposed to. One example of where testing is needed, is whether a system slows down material flow of stone, when pressure rises over certain alarm level the way it is supposed to.

The testing process is very slow and Barney finds it very boring, which is why he often surfs in the Internet during it. However, the work is easy to outsource. Barney has produced himself a protocol document for the process, which tells the subcontractor how to conduct the testing. One testing project can have 600 features and one feature takes approximately 5 minutes to test. The automation team has estimated that testing one system takes about 40 to 50 hours, which makes it expensive. Barney has resources to buy testing from outside, but at times he has to do it himself. It all depends on how the other project phases are advancing.

Role 6: Project manager

Barney estimates that 10% of his time goes by handling the overhead that is caused by handling the projects, that is, calling for offers, receiving offers, checking and approving invoices, asking subcontractors about details and explanations concerning various figures etc. For example, when analyzing invoices, he might find that an employee of a subcontractor has marked an 11-hour workday, which can seem implausible, if he knows that the same person is working on multiple projects. Barney uses mainly phone and e-mail for conducting these tasks. He finds phone calls to be an effective tool for prompting subcontractors, for instance.

Project management includes also recording and reporting what you have done and getting an approval for it. E.g. costs and schedules need to be monitored, reported, and approved. Barney monitors subcontractor's working hours, but not his own that closely. If the subcontractor's working hours exceed what is in the contract, it results in penalties. That is why the requirement specifications in the specification document need to be very precise so that the subcontractors can evaluate the costs more accurately.

Role 7: Observer of machines at worksites

Approximately 10% of Barney's time goes by visiting the worksites, in which Barney physically goes to the customer's mine and observes the machine to see whether it works properly. It's not the customers who invite Barney to visit their worksites, but Metso that sends him to gather valuable testing information. The customer owns the machine so it is actually a favour in part of the customer, which is why Barney often brings some small gifts with him for the customer to show them gratitude, such as a bag of rolls or caps. The observing involves pressing buttons and watching what happens. For example, he might adjust certain values so as to test the machine's functions.

Barney then writes reports out of his observations during his visits. The information that he gets gives him ideas how the machine could be modified to perform better, which he then turns into specifications for the programmers. There is a periodical cycle where a new version of the automation software is developed, tested, installed to the machines at the worksites, and again observed in action.

Overview

Barney's job as an automation engineer involves seven roles. The part of his job that demands most competence is designing the automation specification, whereas answering questions and testing the software are more routine roles by nature. Table 8 presents Barney's roles as an automation engineer.

Table 8 The roles of Barney's job as an automation engineer

Job	Roles
Automation engineer	Designer of automation specifications
	Requirement specification informant
	Support person for programmers
	Technical support person
	Tester of automation software
	Project manager
	Observer of machines at worksites

Barney's workdays are varying. They depend on the amount of support queries he gets and on the phase of the projects. On other days, support can take a great deal of the day and on others none. Some days go by just testing the automation system.

The most important part of Barney's job is to understand the technical requirements received from the other expert engineers and product managers and then designing an automation system that fits those requirements. It requires logical thinking. He also has to think, what kind of language is understandable for the user manuals, which requires English skills and understanding of common sense. Barney's job also requires an ability to understand what the machine concretely does in a 3-dimensional world. When Barney visits a machine at a worksite, he imagines in his mind how it would work, if he would makes certain changes to it. The creativity part in it is to watch the machine at work and then getting an idea how it could be controlled, and then going back and turning the idea into specifications.

3.4 Huckleberry at Infotron Inc.

3.4.1 Organization

Huckleberry (fictional name) works as a customer service associate at Infotron Inc. (fictional name), a multinational Internet business company that is in the Internet marketing business. He has an educational background in marketing.

Infotron has several thousand employees around the world. The company is divided in half by its functions—the engineering function, which designs products and services, and the sales function, whose role is to create revenues. The sales function has approximately two thirds of all the company's employees. The sales function is divided by the size of the customer companies. The bigger the customers are, the more service they get. To mini and middle-size customer companies, Infotron provides more scalable services. The mini and middle-size customer (MMC) unit, where Huckleberry works, operates around the world, but is divided into regional market teams. The MMC unit's central office in Europe is located in the city of Stockburg (fictional name). Every country has also its own office, thus not all employees of MMC work at Stockburg. The Stockburg's MMC unit employs some 200 people. Figure 12 presents a simplified organisational chart of Infotron Inc.

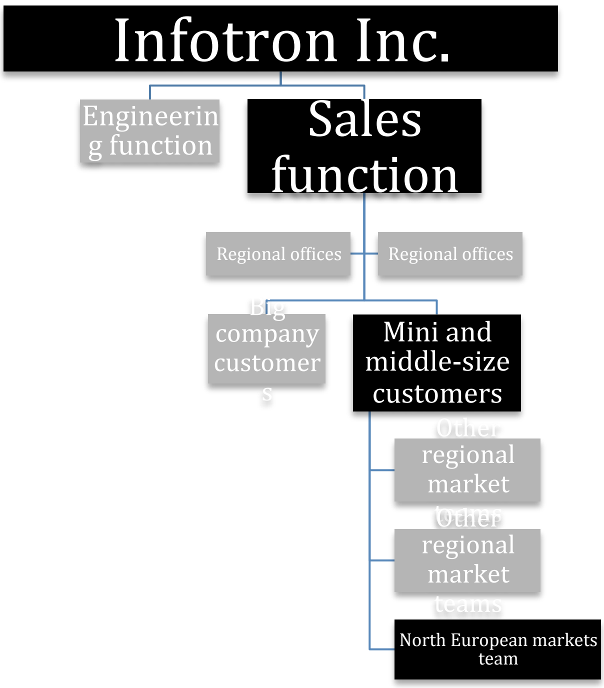

Figure 12 Simplified organisational chart of Infotron Inc.

Huckleberry belongs to MMC's North European markets team for linguistic reasons. The team has some 20 members and is lead by two team leaders. The regional offices have functions that need to be kept up to date. E.g., bigger customers, who need better service, need salesmen serving them in the country. The regional offices also have regional directors, marketing, and other functions that belong under the sales function. The Stockburg office only has sales and marketing, although they operate differently. The mission of Stockburg's North European Region Market team is to sell advertising space to North European mini and middle-sized firms in the Internet.

Business processes

The company can be viewed as consisting of a network of teams with different expertise. The size of the teams can vary between 5 to 20 people. Every problem class has its own specialist team that is 100% involved in it, that is, they have deep knowledge in the area. For example, marketing team lacks technical knowledge, which technical teams have the most. Huckleberry's customer service team handles some technical knowledge. They are specialized in handling technical problems that the customers have faced, but they also sometimes need to escalate problems that require higher-level technical know-how to the technical teams. There is also an invoice team that has the greatest proficiency in invoicing, to which Huckleberry's customer service team direct more complex invoicing problems, in case they cannot handle them themselves. The customer team has the widest range of knowledge, covering some technical, marketing, and invoicing expertise besides knowledge on customer interface. In order of the widest range of knowledge, customer service team has the most, which is followed by marketing team, technical teams, and finally invoicing team.

The biggest challenge of the unit

The biggest challenge of the North European Market team is to optimize efficiency and customer satisfaction. The main question is: How can you maximize efficiency without lowering customer satisfaction and economical result? There have been various experimentations such as different ways of answering e-mails or serving customers

3.4.2 Roles and tasks

Huckleberry's job title at Infotron is customer service associate. In Infotron, the roles in jobs vary depending on what one is interested in and how one wants to develop one's career. People with same job titles have often very different roles.

Role 1: Customer service person

Huckleberry's core role is customer service, which can be consultation or reactive service. The role accounts for about 40% to 50% of his time, although it varies. The work is done in the North European MMC team, where there are people from many North European countries. It is routine work and involves mainly responding to e-mails and speaking over phone. Although routine work, it offers a lot of challenge, because the companies' problems are often complex. It took Huckleberry at least a year to become confident in his skills in the job, although he and his colleagues still need to ask others inside the company, because the amount of knowledge is immense that is needed in the role.

As no one in the team can know it all, employees have specialist roles. The areas of specialty vary from products to technical know-how. Thus there is a strong support network inside the teams. Huckleberry is specialized in mobile issues and he is the one to answer when there's a question about mobile advertisement.

The customer service is divided in terms of customer problems. There are altogether around eight categories of problems. Some problems are more common than others, and others require more time, because there are contractual aspects that need to be clarified. Some problems need to be escalated to another team, which takes time, whereas others are easy and quickly handled. These include certain technical questions about products.

One major problem area that takes lots of time is invoicing. It is a very big, complex, and time consuming area, because there are so many ways that customers get billed. Huckleberry has to have a lot of information on them and to know how to solve them. It is often the most frustrating and most complicated part of the role. The process and the steps of checking the customer's case are very precise. Infotron has five different ways of how the customer can pay one's bills. They are each very much their own kind and the solutions to them are also different from each other. Solving the problems isn't straightforward—it requires creative problem solving and coming up with ideas to find out the cause behind the problem at hand.

Usually customers inquire about the various cost names written in the invoice after a purchase.

In the customer service, the goal is that the customer gets a valid and correct answer so fast that the customer becomes satisfied. At the same time the process needs to follow a rigid processes, especially in invoicing, which are based on economical interest. After a while, an intuition develops that tells you where first to look for an answer. There is, however, also explicit material in the company's intranet, where one can check good ways to solve various problems. Often it is so that, e.g., 80% of cases could be solved with some kind of manual. The manuals get produced, when people with tacit information about invoicing, for instance, decide to make their tacit knowledge explicit and they get taps into their backs, when they do so. Huckleberry could produce those manuals himself as well. However, in phone calls, there's no time to resort to manuals, which means Huckleberry needs to use his intuition, which fortunately has developed as he has garnered more and more experience.

One can recognize a solved problem by looking at historical data and seeing that the same kind of problem is repeatedly linked with the same kind of solution. If the problem doesn't get solved and the customer is unhappy, it counts as failure, in which case Huckleberry has to return to the issue later, e.g., via e-mail. The reason might be that the customer doesn't understand the rationale behind certain costs in an invoice. Huckleberry might have to clarify to the customer, for instance, that there has been a certain number of clicks and where the clicks have come from. Then he might also need to explicate a timeline, which shows where and when the costs have come from.

Role 2: Contact person between customer service and regional marketing teams

Huckleberry is the marketing contact person between his customer service team and the national offices' marketing teams. The role takes about 5 to 10% of his time. In the role, he supports the national offices in their marketing functions, as he has more customer interface expertise.

Huckleberry also handles the communication, if his team needs something from the marketing teams. He communicates daily with the regional marketing managers of North European countries by phone, e-mail, or chat. For example, a regional marketing team might need more information about some product or service and they ask Huckleberry for details.

He then gets an answer from his teammates, who have become experts in the products, as they tackle customers' technical problems on a daily basis.

On a practical level, Huckleberry, for instance, finds out for a marketing team how some process is to be conducted. A marketing team might need to know what kind of invoicing alternatives Infotron's customers have. Another example is doing preparations for making advertisement videos, such as checking licenses. He mostly uses internal resources for searching information. All in all, the activities are numerous and are hard to name and describe comprehensively.

Role 3: Member of company support centre development project

In the company support centre development project, Huckleberry has been producing ideas for the company's support centre service in the Internet. The support centre is where customers can first check for answers to their problems, before directly contacting the company. As a result of the development project, the support centre's search and browsing functions have been enhanced. For example, the system now gives suggestions. Business customers' questions related to VAT, for instance, are now better covered due to the development project. However, customers are generally lazy and do not want to go through the trouble of finding and reading the solution themselves. They rather tell about their problem to a live person, because they then feel they can trust the answer more. Huckleberry thinks that speech recognition might one day offer a technical solution to this, although not yet, because the problems in the customer support are so complicated.

The process in the project goes so that Huckleberry works in customer service and gathers experience, which he then develops into a general view of the problems. Then he goes to a project team meeting with his ideas and hears ideas from others, and together they plan. The team meets once a week, and in the end of the meeting the team leader hands out weekly assignments to the project members. The assignments might ask the members to come up with ways to optimize the site's search for better search results.

Huckleberry's experience in the customer interface is essential, because the people who work in marketing often lose touch in what the customers really appreciate in the company's products and marketing. His role is thus to bring the customer's perspective into discussion. By using analyzing tools Huckleberry can see, for instance, what search words the customers have used and conclude what the customers have probably been looking for. For instance, customers have often entered the name of the support centre itself, which initially perplexed Huckleberry. He then concluded that the customers have probably been looking for the place for logging into the service. Therefore the team finally decided to manually optimize the search result for logging in upwards, when a customer enters the support centre's name.

Role 4: Member of market trend analysis project

Huckleberry has also worked in projects for analyzing market trends, where a working team is formed to investigate what is behind certain market figures that were given to them and write a report. It requires analytical skills and pattern-recognition that in this case mean the ability to identify causes behind a trend. It is also beneficial to have broader understanding of the economical situation in the markets and to know the relationships. Huckleberry finds these projects especially interesting.

Overview

Huckleberry's job as a customer service associate involves four roles. A major share of Huckleberry's job is routine customer service. The company is aware, however, that the customer service is not the most interesting role and reason why people want to work for the company. Besides that, his job involves projects that produce concrete results for the company and are handled by cross-functional teams. He is part of around five business development projects at one time, although the number keeps changing. Altogether Huckleberry has taken part in approximately 10 projects. The roles of Huckleberry's job are presented in Table 9.

Table 9 The roles of Huckleberry's job as a customer service associate

Job	Roles
Customer service associate	Customer service person
	Contact person between customer service and regional marketing teams
	Member of company support centre development project
	Member of market trend analysis project

The organisation is very alive, which means that job roles change often. For instance, once it so happened that Huckleberry was on vacation and when he returned back work, his job priorities had been completely changed and he had been assigned to new projects. However, he thinks it makes the job more interesting. The customer service is, nonetheless, lasting part of his job, although its share of the working time changes constantly. The kinds of projects are many. They can be, for instance, preparing a launch of a new product. Another can be developing the company's internal support, which is related to Huckleberry's marketing contact person role.

3.5 Wulle at Businessor Inc.

3.5.1 Organization

Wulle (fictional name) works as a societal relations assistant at a multinational IT solutions company, Businessor Inc. (fictional name). He has educational background in university level business studies.

Businessor employs thousands of people around the world and several hundred in Finland. The business lines are roughly divided into services and selling products. The services are mainly consultation or maintaining servers. Products are servers and software. The company can also be divided by customer size. Moreover, the company does partnerships with other IT companies. Besides business lines, Businessor is divided into regional units. The Finnish unit, where Wulle works at, belongs to Businessor's European region. Wulle's department is not a business line, but a support function, which serves all business lines. Most closely it is related to marketing function.

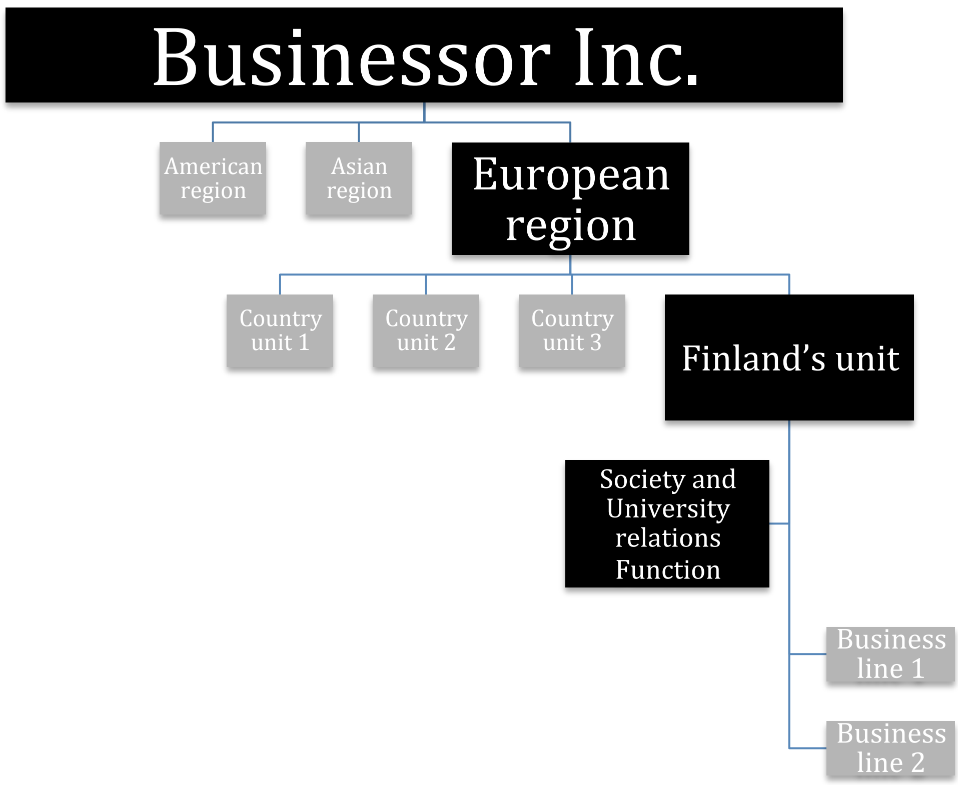

Figure 13 Simplified organisational chart of Businessor Inc.

The organisation, where Wulle works in Businessor, is called Society and University Relationships Function. It is headed from Businessor's European headquarters and has country units in various European countries. Businessor's Society and University Relations Function in Finland has only two employees—Wulle and his supervisor, who is responsible of the function.

Business processes

As it is an organisational support function, one of the Society and University Relationships Function's characteristics is that it has internal customers throughout the organisation. The function participates in societal discussion for the company's business lines. Its area of interest isn't restricted to only public organisations, but society in general, which includes public institutions as well as companies, whose business is related to the project at hand. When the Ministry of Communications prepares IT strategy for Finland, it encompasses many things, such as how IT education should be arranged in Finland. The function takes part in national strategy meetings that cover a wide array of topics related to technology, universities and society. The mission is to create agendas so that they can transform into demand. This is achieved through building customer awareness so that the customer knows what it needs and what it can ask from Businessor. As the customers are dealing with new technological solutions, they don't always know what is even possible. For example, there might by societal discussion about the fragmentation of the national medical record system and its various solutions, in which Businessor participates.

The mission of the university relations is to do research and bring in the right kind of employees and their skills. Thus the mission is to recruit and do research partnerships. Businessor gets requests from universities and companies, where it is asked to contribute or fund researches projects. Generally, the research has to have some concrete impact on Businessor's business and Businessor's employees need to be involved. The research produces information that is relevant to Businessor's business lines.

The supervisor of the Finnish unit goes to visit different political parties in order to tell about, e.g., Businessor's perspective on information society strategy and how various ICT solutions have been implemented in different countries that are currently in discussion in Finland. This work builds a base for the demand for Businessor's solutions. Often the solutions are so complex that it requires that the decision-makers are educated about them. One such project was a road toll that was implemented in a European metropolitan city. Telling the political parties about the implementation of that project stirs interest and creates understanding, which can lead to more demand for Businessor's solutions.

Biggest challenge of the unit

As the Society and University Relationships Function is not directly related to serving Businessor's customers like in the case of business lines it is easier for employees and managers to disregard it. Since time is a scarce resource, Wulle and his superior often have hard time urging things forward. This results in longer response times to messages and the need to prompt people more.

3.5.2 Roles and tasks

Wulle's job can be divided into two parts. The first part is projects and the other financial administration. The projects responsibility can be divided into two types—university and society relations—in which the latter includes both the state and municipalities. The two project types both have their own cost centres. In the financial administration role Wulle handles the two cost centres. The university relation's budget comes from Finland and society relation's budget from Europe. Wulle estimates that the projects take between 70 to 75% of his time and the rest goes with financial administration. As for activity, Wulle sits half of his time at his workstation and the other half he sits in the meetings.

Role 1: Event organiser

Events serve as a recruiting channel for Businessor. As for members of student organisations, events act as a way for finding jobs and getting knowledge about employment opportunities. Here Wulle has a central role, as he alone is responsible for organising the events as a part of handling university relations. If, for instance, Businessor has the need for junior consultants or programmers, Wulle first thinks, which universities have the appropriate education lines and then contacts them. Student organisations serve as the link for reaching the students, who are the potential recruits for Businessor.

The process of organising events begins, when Wulle receives an order. The orders come either from Businessor's internal departments, such as business lines or functions, or student organisations that wish to have their member's gain knowledge about Businessor as a company and employer. If Wulle accepts the order, he then determines the topics of the event by considering the properties and needs of the company's departments and the visiting student organisation. If the need for an event comes from inside, then the theme is often related to the work, which the department wants to recruit people for. In case the need comes from a student organisation, then the agenda is determined by what the people study. Wulle's general knowledge helps in thinking relevant event topics for the visitors. He has an idea, for example, what things about Businessor are relevant to information science students and what is the reason they want to know more about the company by using his own knowledge that he has gained from the media and discussions.

Naturally, organising an event requires scheduling, reservations and making detailed arrangements with the student organisation. In this task, Wulle looks for empty slots in the company calendar and asks the student organisation, whether they would like to come to an event at the given time. The student organisation then checks which empty slots fit their schedule and makes suggestions. After that they agree on the first preparatory meeting. Wulle then holds the preparatory meeting with the student organisation, during which they make arrangements and choose the time for a second preparatory meeting. During the meetings, he always prepares memos, which he then e-mails to all participants afterwards. Following this, he makes sure that the student organisation informs its members about the event, after which Wulle starts receiving enrolments. Before the event, Wulle uses the company's intranet to reserve all the necessary premises, such as a room or auditorium and a video projector.

Another part of the organising role is to get relevant speakers. From the list of employees and company's calendar he can check the availability of employees at any given time. After that Wulle ranks the most appropriate candidates for speaking in the event and asks the people in order by e-mail or phone. The key speakers in business lines' event are most often the business line managers. Wulle can also ask them, whether they know someone, who knows about a certain topic and is good in speaking about it. Often Wulle invites Businessor's innovation manager to hold an inspiring introductory speech. On other times, a topic might be new or unfamiliar, which makes it more challenging for Wulle to think, which Businessor employees are fit as event speakers for a particular theme. In the end, the objective is to get a good set of speakers, who can cover the relevant topics well for the visitors.

Sudden problems occur all the time before and during the event, and Wulle needs to solve them ad hoc. For instance, from time to time speakers get sick a day before an event. This problem Wulle handles by asking if some other speaker could speak for longer, whether someone can hold the same speech, if someone can give another speech, or by having the audience do a case exercise for longer. Such backup plans Wulle has learned by looking at memos and slides from earlier preparatory meetings and presentations. Wulle always notifies everyone involved, if the program changes.

Role 2: Meetings attendant and coordinator

Meetings are vital for Businessor for coordinating projects with collaborators. Attending meetings is also an essential role in Wulle's job. Both, the university and societal relations, involve a lot of meetings, which Wulle participates in. The university relations management team's mission is to coordinate Businessor's university cooperation, which includes research and other large projects. In society relations projects, Wulle and his boss attempt to convince public decision-makers in the meetings of Businessor's perspective on societal issues such as how the nation's information society strategy ought to be implemented in practice. Wulle's meetings usually take place at Businessor's office or at the customer's office. Since transportation takes some time, they are preferably held at Businessor's office. In general, transportation does not take much more than half an hour per meeting. Usually, the meetings have between three to ten participants. The participants can be civil servants or representatives of various companies. It is also essential for Wulle's function to understand what the real agendas of the participants are. The language of the meetings is Finnish, if there are only Finns participating. The meetings begin typically by going through how a particular project has advanced as a whole, which is when Wulle usually speaks on the behalf of Businessor or his function. In the meetings he explains what Businessor or his function has managed to accomplish regarding to the project plan and describes how they have managed to do so.

At Businessor they sometimes have *calls*, which are telephone meetings, where a manager calls from abroad and there is one same level person from each country. Usually they are about projects that are implemented in all Businessor's country units at the same time, and the project is coordinated from the European headquarters. The purpose of calls is to share information about how things are going in the other European units and to ask, whether some country unit needs certain information. Calls can have between 2 to 50 people on line and are held in English. If Wulle is the only person participating from Finland, he uses a cell phone, but if more people are in the same room, they use a speaker. In calls, Wulle's role is to participate in discussion, but at times he does mainly things related to coordinating the project, that is, he listens to the discussion and writes down tasks and dates that his function agrees to take on. Finally, Wulle composes and sends an e-mail, where the current situation is explained, what has been agreed upon, and when will they see the next time.

Since Wulle's role in the meetings is mainly operative, he usually doesn't comment on policy issues that are under his boss's domain. Sometimes he is assigned to a project coordinator role, which is when Wulle talks more. Otherwise he is in the role of being an observing participant, although his roles vary in the meetings depending on the size of the project. When the meeting is about a large project, and his boss is attending, his role is mainly to gather information by listening and taking notes, but in smaller project he gets to say more.

Towards the end of the meeting, Wulle, in case he is the project coordinator, sums up the discussion and directs the group's focus on planning for how to continue. The planning covers issues such as what the group wants to get done next, what does it require of them, who does what, who knows who for contacting, and when will they see for the next time. The planning phase also involves assigning responsibilities to get information about issues that still remained unclear in the meeting or to contact and invite people or organisations to the next meeting.

Role 3: Project member and coordinator

As a project coordinator, Wulle's main task is to prepare agendas for the meetings based on his notes from previous meetings and discussions with his boss. In general, he takes care that things go as planned between the meetings, that is, he monitors the project's schedule and creates roadmaps how to get things done. This is needed, because the other project members soon forget what has been agreed on. They also need to be prompted; otherwise the project will not advance in time. Mostly the task is about fitting schedules together and understanding what needs to be accomplished next, which person is likely to get which task done, and in what time. Wulle needs to make good estimations on time.

When a project team is unable to reach clarity on some issue during a meeting, it assigns some of its member to conduct an investigation on the subject. When Wulle's function gets the responsibility, it is usually Wulle, who conducts the investigation. Investigations include, for instance, finding out whether the technology agency of Finland has had similar projects before, and if so, what organisations have been involved. In such cases, Wulle contacts the various relevant organisations and explains them what the project is about and what stage it is at and attempts to persuade them to join the meetings.

In order to coordinate projects, Wulle needs to constantly get information from the project members. When a project involves multiple people, Wulle uses e-mail, which allows sharing information with multiple people and asking them to information about their status. He then compiles the information that he has gotten from the project members and sends the compilation to them about the status of the project. Yet, Wulle might have to call people individually about particular issues.

Role 4: Financial administrator

As Businessor is a large multinational company, it demands a lot of bureaucracy and financial administration to keep track on all its financial transactions. The societal and university relations function engages in a lot of collaborative work with outside organisations that involves giving donations to different societal and university projects. Such societal projects include those associated with business clusters, whereas university projects are usually research collaboration.

Wulle handles his financial administration role side by side with the projects. It includes making quarterly budget forecasts, monitoring actual costs, handling bureaucracy associated with donations and making payments. He is responsible of two cost centres to which the company allocates money. Wulle uses the cost centres' accounts for paying invoices such as university research project contributions.

Financial administration becomes relevant especially between quarters. That's when Wulle receives inquiries from the Businessor's European headquarters about how the Finnish unit is performing. Wulle responds to the inquiries, makes forecasts and handles the other issues that are related to his two cost centres. As the university relations function is directed and funded from Businessor's European headquarters abroad, they are not able to forecast exactly how much money Wulle's unit in Finland has and how much it needs. Sometimes the Finnish unit needs more funds and then he has to request extra money from the European headquarters.

On a practical level, Wulle uses a spread sheet program for budgeting and making records to the company's system and making payments. Budgeting is based on action plans and involves mainly looking at the same quarter's action plans and figures in the previous year and estimating the next quarter's budget based on those figures. Usually Wulle budgets the same amount of money, but sometimes a little more or less, depending on whether the situation is different that year. If there are bigger projects, they have their own unique budgets that are created along with their action plans. At the same time he has to keep in mind that there is only limited amount of money. In doing forecasts, Wulle has to estimate how much more money his function is going to spend in the current quarter. He checks the function's plans and sees, which costs have remained within budget and which have not. Based on this Wulle forms an estimation of the future spending. Finally he sends a report to the European headquarters by e-mail.

At a certain point of a project, Wulle needs to pay invoices for the project to proceed. Paying invoices requires getting approvals from the relevant business line managers, and providing them with written justification, why making the transaction is necessary. Since the money comes from their budgets, they need to know how it is spent. Besides company's process manuals, Wulle has learned to do the approval process from his predecessor in the same job, as there is a lot of tacit knowledge required to do the task that is now found in documents. Making the payment itself takes only five minutes for Wulle, but the whole process is long. For smaller sums it is enough to have a business line manager to approve the invoice, but for bigger sums, there needs to be an approval also from the financial manager on top of the business line manager. In short, Wulle makes an invoice into the system and indicates which manager needs to approve the invoice, after which the system notifies the manager, who then approves it at some point. In practice, the managers are so busy and get so many e-mails a day that it often takes a day or two for them to approve invoices. In that case, Wulle has to walk to the manager and ask him or her in person to approve the invoice.

Wulle also needs to fill in forms for the purpose of avoiding accusations of bribery against Businessor by indicating what the company gets in return from its contribution. For filling in the forms, he sometimes needs to ask department managers by e-email, which cost centres the funds are to be taken from. In many cases, however, he has learned by heart, which cost centres to use. The managers do the approving by logging into the company's internal system, where Wulle has prepared the invoices for them.

Wulle also needs to plan, where the money is coming from. If there is some special case, he can apply funds from abroad, or similarly from Finland, if the funding normally comes from Finland. The funds are always earmarked before they are used.

Overview

Wulle's job as a societal relations associate at Businessor involves four roles. The job contains predominantly non-routine work. Table 10 presents Wulle's role.

Table 10 The roles of Wulle's job as a societal relations associate

Job	Roles
Societal relations associate	Event organiser
	Meetings attendant and coordinator
	Project member and coordinator
	Financial administrator

Wulle's days are varying. On some days he sits the whole day in the office at his workstation, on others the whole day goes at meetings. On some days there's some of both. Handling and scheduling the various meetings requires project management skills. One has to be able to fit schedules together and see the big picture. Estimating time and capabilities of various employees is at essence.

4 CONSTRUCTING A FRAMEWORK FOR KNOWLEDGE AGENT'S KNOWLEDGE CAPABILITIES

In this Chapter, I present the framework for knowledge agent's knowledge capabilities. Despite the fact that numerous cognitive models exist, of which two was presented in Chapter two, I decided to construct a framework of my own, which I organised using the empirical evidence. I chose to do this, because I wanted to use a framework that suits the empirical data, study method and setting better. The framework has three main capability categories based on in what direction information is flowing. The main categories are information input that also includes information interpretation, information processing capabilities, and information output capabilities that also include physical action.

4.1 Input capabilities

Perception: The capability to take in visual and auditory signals through senses or sensors, such as verbal speech, text, pictures and other visual information, to be encoded and interpreted by the knowledge capabilities.

Receiving data: The capability to take in digital information that can be then encoded and interpreted by the other knowledge capabilities.

Interpreting natural language: the capability to recognize and interpret words and sentences and to associate them with relevant meaning and knowledge for the purpose of forming knowledge of the situation. In this study it also includes the capabilities to receive information in natural language from the external environment by reading or hearing.

Interpreting visual information: the capability to perceive visual information, recognize visual phenomena and interpret them in terms of some perspective or framework.

4.2 Information processing capabilities

4.2.1 Central processing capabilities

Learning: The capability to build knowledge out of information and to become better at performing tasks through experience by associating phenomena and concepts through correlation and inference. In principle, learning takes place in every situation where one or more capabilities are utilized. Through learning, capabilities can be refined to competencies.

Knowledge: in the context of this research project, knowledge is the capability of semantic understanding, that is, it is the capability to activate and load complex knowledge that is stored into the knowledge base of a knowledge agent at any given moment. Knowledge is formed of conceptual entities and their relations to each other. This leads to a formation of complex, contextual, semantic understanding and allows transmitting the activated knowledge to be processed by other knowledge capabilities. Thus, knowledge can be considered as a central node of the whole cognitive process. For example, if a conceptual entity 'tree' is activated and loaded from the knowledge base and knowledge becomes knowing, the knowledge agent knows that trees usually have leaves and roots, thus trees have a possessive relation to leaves and roots. At the same time, a knowledge agent's experiences related to trees may be activated. The complexity of the capability of knowledge allows a knowledge agent to have perspectives on things, and with values and relevance evaluation, opinions as well.

Structured knowledge: a rigid capability to process structured knowledge to form simple understanding of entities and their relations to each other, which allows interpreting and making inferences from knowledge. In structured knowledge, the conceptual entities and their relations are clearly defined, which is why it could also be called categorical thinking. Whereas knowledge allows having versatile and complex perspectives on things, structured knowledge is based on facts. E.g., mathematical operations and working with structured information in tables. In this framework, structured knowledge is considered as a component of knowledge.

Relevance evaluation: The capability to recognize how different elements of concepts, contexts, scenarios and goals are relevant to one's values. It allows assessing the importance of different situations, entities, attributes etc. High competence in relevance evaluation leads to more effective decision-making, as the knowledge agent is able to concentrate and calculate more accurately the impact of each constituent of a situation to goals and values. A knowledge agent with poor relevance evaluation capacity gives too much focus on things that are not as important to goals and maximizing desired values and minimizing undesired values. Intuition or common sense can be thought as to be close to relevance evaluation when a person knows almost instantly from a set of alternatives what he or she thinks is essential from the information given. People with strong egos and high intelligence may be thought as having strong relevance evaluation capacity in regards to one's own position and self-interest.

Relevance evaluation can be characterized as the processes that the prefrontal cortex performs in the human brain. In his theory of Dynamic Filtering Theory, Shimamura (2000) proposes that the prefrontal cortex has a central role in executive functions like attention. The prefrontal cortex is assumed to function as a high-level filtering system than amplifies goal-directed activations and inhibits irrelevant activations. Miller and Cohen (2001) proposed in their Integrative Theory of Prefrontal Cortex Function that "cognitive control stems from the active maintenance of patterns of activity in the prefrontal cortex that represents goals and means to achieve them. They provide bias signals to other brain structures whose net effect is to guide the flow of activity along neural pathways that establish the proper mappings between inputs, internal states, and outputs needed to perform a given task". According to Ernest (1990), in artificial intelligence research, common-sense knowledge is the series of facts and information that an average human is assumed to know. The problem of modelling common-sense knowledge is thought to be one of the most challenging in all of AI research since the scope and exactness of common-sense knowledge is huge.

Values: The underlying forces that determine what kind of events are desirable and what are adverse for a knowledge agent. Values dictate what scenario categories are to be approached and what are to be avoided. They set fundamental parameters for relevance evaluation and goal formulation. In the end, all actions of an agent are to serve its values. Growth, reproduction, and survival are examples of basic biological values and scenario categories, whereas honesty, loyalty, and prudence are examples of socially derived values. In the case of humans, emotions can change values temporarily and create contradictions between the individual's temporary emotional values and one's standard values. For example, under the emotion of bitterness, a knowledge worker's morale could fall resulting in one's loss of interest in being productive and even in adopting a goal of sabotaging the work of the organisation. However, once the emotion subsides, the individual's standard values set back in and start guiding one's goal formulation and other actions again. For this reason it is important to manage organisations in a way that create an atmosphere of trust and fairness to keep employees' morale high. In the case of computers, emotions are non-existent and the only value is to comply with commands.

4.2.2 Left-hand side processing capabilities

Semantic analysis: the capability to extend knowledge by focusing on some part of activated knowledge, object or a phenomenon in order to identify its constituent parts and attributes. In some cases a formal framework or perspective is utilized. For example, reading through a company's annual report, and discerning information that is relevant from a financial or environmental perspective is a task where the capability of semantic analysis is employed.

Inference: the capability to derive new knowledge on some part of activated knowledge by combining various pieces of knowledge using logic. For example, a marketing director could infer that because more and more people are buying smart phones that allow mobile advertisement, companies will invest more of their marketing resources in that area in the future. As another example, in scheduling work, if a knowledge agent knows that a certain task has a deadline by the end of the month and finishing the task takes at least two weeks, conducting the task has got to start at least two weeks before the deadline.

Evaluating evidence: The capability to recognize information from material that supports or negates a claim or hypothesis. It is based on some level of knowledge, inference, understanding language, and evaluating the credibility of the source.

Evaluating own confidence level: The capability to quantify and evaluate the amount and type of evidence and sources and use this information to calculate the probability that an answer candidate is the correct answer. Little evidence from unreliable sources provides poor confidence, as well as evidence contradicting supporting evidence. An elemental part of evaluating own confidence level is recognizing gaps in own knowledge, where one identifies what components of a piece of knowledge are lacking, and would be the most essential in bringing confidence to a given piece of knowledge. For example, if a patient has fever, then knowing, whether he or she has consumed some unusual food could help raise confidence level in answers.

4.2.3 Right-hand side processing capabilities

Goal formulation: The capability to form viable future scenarios internally that serve certain values or fulfil higher goals. In goal formulation, a knowledge agent combines knowledge of the current situation and knowledge of the laws of the environment to know what scenarios are possible and probable, and internal values to formulate a viable scenario that best fulfils internal values with reasonable input-output-ratio in mind. The capability of goal formulation can be considered crucial in knowledge work as Drucker (1999) stated that in knowledge work the knowledge worker should determine the task oneself.

Synthesizing knowledge: The capability to combine elements of knowledge, concepts and various kinds of information (such as visual or auditory) to generate new concepts, ideas, hypotheses, knowledge, alternative solutions, plans, pictures, pieces of music and sound etc. that might be relevant to goals and values. The act of coming up with alternative plans of action can be considered as a part of synthesizing knowledge. Planning, on the other hand, involves coming up with alternative plans, analyzing their validity and then choosing the most appropriate plan. It can be therefore considered of entailing synthesizing knowledge, semantic analysis, inference, and relevance evaluation.

Categorizing: The capability of recognizing common elements among a set of conceptual units and creating principles by which those units are grouped together under conceptual categories or distinguished from each other. It is an essential capability in building knowledge structures and perspectives on things. Categorizing serves the purpose of saving time and energy by making the environment simpler to handle cognitively, thus enabling inferring and synthesizing knowledge with fewer knowledge processes. It also consists of merging knowledge, where less relevant elements from information are reduced and similar information is assimilated and packed into a condensed form. Merging knowledge simplifies knowledge and thus frees up cognitive capacity to conduct more advanced cognitive functions with the knowledge such as inference and synthesizing knowledge. It is also present when producing natural language in making messages reasonable length.

Recognizing patterns in data and information: the capability to notice recurring patterns in data and information and associate them to similar patterns in some other phenomena that is stored in memory. For example, recognizing a steep drop in sales figures of a product could evoke an association to climb in sales of another, competitive product.

4.3 Output capabilities

Producing natural language: the capability to transform knowledge / semantics into natural language and communicate it to the external world. Includes both written language and speech. Producing natural language consists of being able to choose a structure of messages, choosing appropriate words, producing grammatically correct sentences, summarizing and merging information in order to limit the length of the message

Producing simple language: the capability to form simple sentences, that is, pose simple questions or express answers in simple terms such as "In the year 1570, Elizabeth I was the queen of England". Includes both written language and speech. Does not include the capability of choosing an appropriate structure of messages or forming grammatically correct sentences, but rather using readily formed expressions, phrases, and sentences.

Gesturing: The capability to communicate by using facial expression, body language, and tone and timing of speech in order to express, for example, attitudes and level of confidence and to make certain impression in the receiver. Gesturing may be performed with a physical structure, like with a face or hands, or with a visual interface that shows a physical body capable of showing gestures.

Operating computer programs: The capability to activate a certain computer program and to operate it in order to access, manipulate or produce data and information. For example, using word processors, spread sheets, or presentation tools to produce or change documents, tables, or presentations, or do some operations such as statistic calculations. In requires the capabilities to understand goals, and to give the program commands in order to achieve the goals.

Programming: The capability to translate knowledge of a procedure into a given programming language to make a computer operate in a way that serves a given purpose.

Operating machines and devices: The capability to start, control, open, adjust, and turn off machines by using their physical interfaces or otherwise moving or altering them physically. Controlling an industrial machine or handling an overhead projector are examples of operating machines and devices.

Communication: The capability of passing digital information, visual or audio messages in order to communicate information to other knowledge agents.

Physical action: The capability to use one's physical structure to affect one's environment via exerting physical force, like in the case of pressing buttons or pulling a handle, or by using one's physical structure to express visual communication in the form of gestures.

4.5 The knowledge work agent's knowledge capability framework

From the aforementioned knowledge capabilities a knowledge capability framework for knowledge agent can be put together. Figure 14 presents the framework with all the constituents in place.

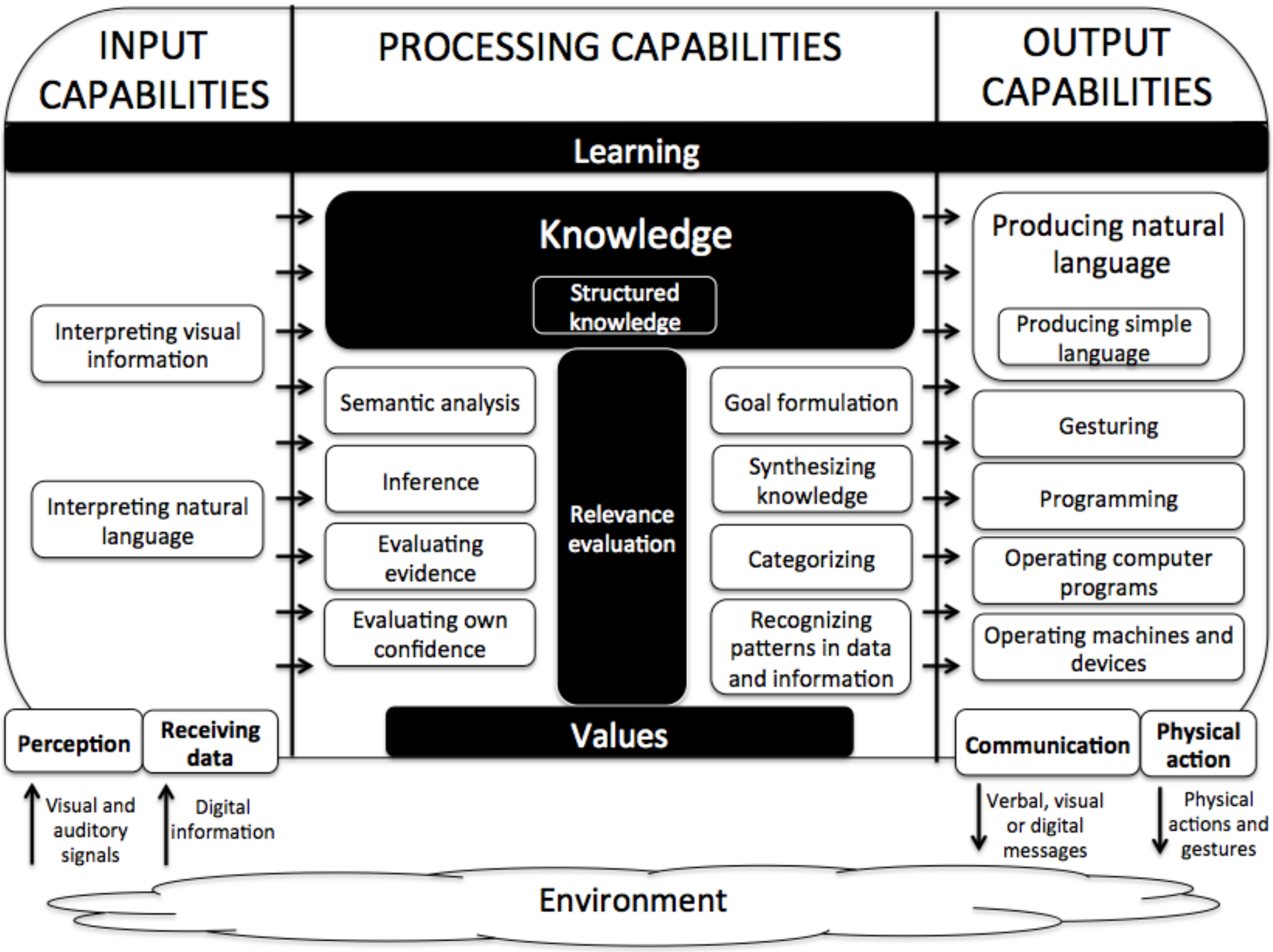

Figure 14 Knowledge agent's knowledge capabilities framework

In the newly constructed knowledge agent's knowledge capabilities framework there are three classes of knowledge capabilities: input capabilities for filtering and interpreting data and information and creating knowledge representations of it; processing capabilities for analyzing, synthesizing and evaluating knowledge; and output capabilities, where knowledge, goals and decisions are turned into communicable information and action. Instead of occurring alone in an off or on state, the knowledge capabilities become activated together and fluctuate in the degree of employment at any given moment.

A knowledge agent receives information from the environment through perception, where visual and auditory cues are transmitted to the other input capabilities (Interpreting visual information, interpreting natural language, recognizing patterns in data and information) for filtering and interpretation. In this process, the information through input capabilities activates knowledge. Another way of saying this is that the incoming data and information creates knowledge representations in a knowledge agent.

In the next class of knowledge capabilities, the interpretations through input capabilities has now loaded up in memory as knowledge, which is the main cognitive process of a knowledge worker. The situational conception or "big picture", which is composed of activated knowledge, takes place in the capability of knowledge. Having the knowledge loaded up in the knowledge allows its further referencing and manipulation. However, no cognitive processing activity takes place, unless there are values that the activity might serve, thus values are the igniting force in the whole process. The knowledge capability is linked to the knowledge worker's values via relevance evaluation capability, which assesses how closely linked the information in the knowledge is to the values. Structured knowledge is part of knowledge, where knowledge is represented according to a simplified model. For example, computer software generally run on structured knowledge, where the input has to be given in a certain terms and the computer then processes the information along a fixed procedure. In the same way a knowledge worker doing purchasing for one's firm could rely on some structured model of knowledge about the features of some machine and strives to get only relevant information from vendors. Thus far only humans have been able to translate knowledge into structured knowledge.

The knowledge capability of learning placed in the top of all the other knowledge capabilities is associated with all the other knowledge capabilities and is activated in parallel with the functioning of the other knowledge capabilities and their interaction with each other. Therefore all events produce learning for the knowledge agent.

As knowledge has been loaded to knowledge that the knowledge worker has evaluated relevant to one's values, the refining may begin. On the left-hand side, there are the knowledge capabilities of semantic analysis, inference, valuating evidence, and evaluating own confidence. Semantic analysis enables investigating and breaking into parts the elements and attributes of the entities activated in knowledge. Inference allows extending the knowledge by making conclusion about the content in knowledge, or conducting logical analyses of various sort. Not all the invoked knowledge is reliable, however, and thus the knowledge worker has to evaluate evidence for any piece of knowledge. This can include evaluating the reliability of the source of any piece of knowledge, the number of sources implying for or against the validity of the knowledge, logical coherence etc. In order to make accurate inferences, it is important to be aware of one's own gaps in knowledge. Recognizing gaps in own knowledge could mean for a marketing director, for example, making a decision about utilization of a new penetration strategy at a given market is difficult, because the firm lacks information about the income levels of a certain focus group. Thus, conducting a market research would fill in the gap. Closely linked to recognizing knowledge gaps and evaluating evidence is evaluating own confidence about any given piece of knowledge or decision. By evaluating one's own confidence, a knowledge worker can help determining the risk level of any given decision.

The right-hand side knowledge processing capabilities are more associated with synthesizing knowledge. The knowledge capability of goal formulation is highly synthetic and enables a knowledge agent to combine knowledge and values in determining worthwhile goals that are reasonably attainable, serve a set of values in a significant degree when attained, and do not carry unreasonable risk in relation to the potential value if not reached. Goals may be high-level and long term, but can as well be low-level, short-term and related to everyday situations, which is why goal formulation is not always conscious, but taking place frequently throughout the day, as a knowledge agent needs to continuously think of and determine the outcome it wants to accomplish next. Closely related to goal formulation capability is synthesizing knowledge, which enables combining compatible entities and attributes together to create new concepts, pictures, sounds, ideas, goals, and solution alternatives. Synthesizing knowledge has thus far been largely in the human domain beyond the capacities of computers. Categorization capability relates to semantic analysis, relevance evaluation, and synthesizing knowledge. It allows the simplification of complex knowledge into chunks that can be worked on more efficiently together. Lastly, in the right-hand side processing capabilities related to synthesizing, there is merging knowledge, which allows reducing the size of a piece of knowledge or information by dropping out less relevant details. Besides knowledge, the capability utilizes relevance evaluation to identify what is essential knowledge to the values of various parties.

Finally, the output capabilities allow the knowledge worker to influence one's environment through communication and action. Often, the most important output capability is producing natural language. It involves translating the meaning in knowledge into language that another human speaking the same language can understand. This process is very complex, and so far this capability remains beyond the capability of computers. However, computers as well as can produce simple language, because in it the sentence structure is predetermined and there are only a relatively limited number of alternative messages that an agent needs to handle. In gesturing, a knowledge worker uses one's body and face to influence the emphasis of various part of a message, and it is tightly associated with face-to-face conversation. Thus, it can be utilized for, e.g., persuasion, inquiry, showing of interest, and disdain among other things. Programming involves translating meaning in knowledge into algorithms to be performed by a computer. Besides knowledge that includes knowing the programming language and relevance evaluation, it involves plenty of goal formulation. Operating computer programs allows the knowledge worker to give commands to computers and software via interfaces in order to do various things, such as searching for data and information, producing information, or manipulating information. Finally operating machines and devices relies a lot on Interpreting visual information besides knowledge, as using the machines and devices often have a physical element in them, with moving parts.

5 IBM'S WATSON AS A TECHNOLOGICAL ENABLER

In this Chapter, I shall delve into Watson, an artificially intelligent computer system, and its DeepQA software. I shall analyse its technological properties and capabilities based on the published data. Most of the information in this Chapter is from IBM's publications, web sources, newspapers, magazines, and journals. Some issues emerged in an expert interview with Finland's IBM's innovation manager, Ville Peltola.

5.1 Watson in brief

> *"When you vision the future, at least when I do, you vision computers capable of understanding and interacting in natural language. My big, big inspiration was the Star Trek computer, where captain Picard or Kirk just starts speaking to the computer. The computer understands the question and what he is looking for, produces answers, gives you confidence, gives you summaries, gives you follow-up questions. That's exciting and that's cool, and I think it just has to be that way. We just can't imagine the future without it."*
>
> - Ferrucci (2010)

IBM's Watson is a highly advanced question-answering (QA) computer system capable of answering questions posed in natural language. It is the fruit of IBM's DeepQA project, under which the DeepQA software underlying Watson is being developed. Taking three years to reach human-expert-level question answering, the DeepQA project is still on-going and conducted by a research team of 20 people led by principal investigator David Ferrucci. Watson is mainly IBM's endeavour, but its development team includes researches from several universities. The computer was named after the first president of IBM, Thomas J. Watson. (Ferrucci et al. 2010)

Watson had its first chance to demonstrate its capabilities in the popular American quiz show *Jeopardy* in 2011, where it competed against the all-time best *Jeopardy* players Brad Rutter, the biggest all-time money winner on *Jeopardy*, and Ken Jennings, holder of the record for the longest championship streak. Watson won the challenge in a two-game, combined-point match. IBM had been foraging for a new challenge, since the victory of *Deep Blue* over the chess champion, Garry Gasparov, in 1997.

5.2 Watson's capabilities

"*The Watson technology set is a solution capable of interpreting large volumes of unstructured data and natural language, providing precision and confidence in its answers.*"

- IBM Corporation (2011)

The unprecedented feature of Watson's DeepQA software is its capability to handle human language and answer questions with evidence using massive knowledge bases. The human user can get an answer using natural language, without having to adapt one's use of language to the computer's. Moreover, it has a useful addition of further technologies like machine learning, risk assessment, and probability (Feldman 2011).

Watson's capabilities can be divided into four. First, Watson is capable of interpreting natural language. Second, it is capable of inference to reason and produce hypotheses. Third, it is capable of producing simple language to give short answers and ask the user iterative follow-up questions in order to get a better grasp on, what sort of an answer the user needs and to increase its confidence. Finally, it is capable of learning from source material and dialogues with users.

5.2.1 Capability of interpreting natural language questions and source material presented in natural language

The Watson's capability to understand natural language has two functions: interpreting the user's natural language questions and analyzing large volumes of source material that consist of unstructured, semi-structured data, and structured.

Interpreting natural language questions

The system needs to interpret and understand natural language questions and identify the kind of an answer that is wanted. Watson does this by trying to understand what the question is asking and executes multiple analyses, which determine how the question will be processed by the rest of the system. DeepQA supports also understanding more complex natural language such as metaphors and wordplays, making it more humane in that sense.

Analyzing large volumes of unstructured, structured, and semi-structured data

Answering natural language questions in real time requires a great deal of parallel processes and comprises of a number of phases. A knowledge base is needed to access source material. The content can be loaded up to Watson's memory or alternatively it may access the Internet.

A DeepQA system can go through and analyse massive amounts of data in text form that is unstructured, structured, and semi-structured in nature. Unstructured data, such as the text in e-mail messages, documents or web pages, is unmodeled and cannot be found in fixed locations, whereas structured data has a data model and resides in fixed fields within a record or file such as relational databases and spread sheets. Semi-structured data is neither raw text, nor is it table-oriented.

As mentioned earlier, the original Watson was capable of processing 500 gigabytes of data per second, equal to one million books. One has to keep in mind that Watson is a powerful application of DeepQA software consisting of state-of-the-art computing hardware. With a less powerful computing hardware, DeepQA does the same work, but with longer processing times.

5.2.2 Capability of inference to reason and produce hypotheses

Firstly, Watson can generate hypotheses or answer candidates by first taking the results of the question analysis, and then searching its sources for relevant content (Ferrucci et. al 2010). This as a process is comparable to a person doing queries with a search engine.

Next, it generates hundreds of answer candidates by extracting answer-sized snippets from its search results. All answer candidates that can be associated with the question are regarded as hypotheses for the final answer, which Watson then attempts to prove correct with a degree of confidence. (Ferrucci et al. 2010). For example, if the question is asking for a politician, then all people that the system identifies as politicians count as hypotheses.

Secondly, Watson can evaluate the hypotheses by gathering supporting evidence. Via a variety of integrated evidence collecting techniques, it gathers evidence to support each hypothesis, and then scores each piece of evidence to form a degree of certainty for each hypothesis. It can use various reasoning methods, such as geospatial and temporal reasoning. (Ferrucci et. al 2010). For example, in case a question asks for a landmark in Europe built in the 1800's, it provides more evidence for the Eiffel tower over the Statue of Liberty or the Tower of Pisa, because the latter two answer candidates do not find as much combined support from the geospatial and temporal reasoning.

Finally, Watson is able to quantify confidence in answers by ranking the hypotheses so as to formulate a final answer that is supported by highest scoring evidence and a confidence level, that is, the probability it is correct. (Ferrucci et. al 2010). In *Jeopardy,* for instance, Watson was able to use the confidence level in betting decisions and managing risk.

5.2.3 Capability of producing simple natural language to give short answers and ask the user iterative, clarifying questions

After Watson has processed the original question and come up with hypotheses, it then expresses the answer(s) either by text or speech. Alternatively, it may pose simple clarifying questions to the user iteratively. This is done to improve precision and confidence by gaining a clearer understanding of the context. The innovation manager of Finland's IBM, Ville Peltola, put it in the following way:

> *"When the user is not sure, what he means, a DeepQA computer can ask a clarifying question to grasp, what the user is after. It asks the human user iteratively and each answer given by the user is a clue for Watson that narrows down or particularizes, what is being asked. This kind of system will be able to answer more accurately. No longer does it need to be an answering machine that gives just a single answer to a single question."*

As an example in medical context, a person might ask the system what helps for heartburn. The system might then ask what medication the person is taking, or whether he or she has had certain other symptoms lately.

5.2.4 Capability of adapting and learning to improve results over time

A DeepQA-run system like Watson is capable of learning by going through volumes of texts and analyzing them. It uses statistical correlations to find structural, syntactical, and semantical patterns in the text. For example, it can learn that inventors patent inventions, or that officials submit resignations. By aggregating information, the system can learn to use it more effectively in order to improve the speed and accuracy of its answers. It can also learn from how people use language, even when it is not abiding formal definitions or other linguistic rules. For example, fluid is not a form of liquid, whereas a liquid is a form of fluid, but Watson was able to notice that the way people actually use language allows it to consider fluids as liquids. (Ferrucci 2010)

The technique of learning is depicted in figure 15:

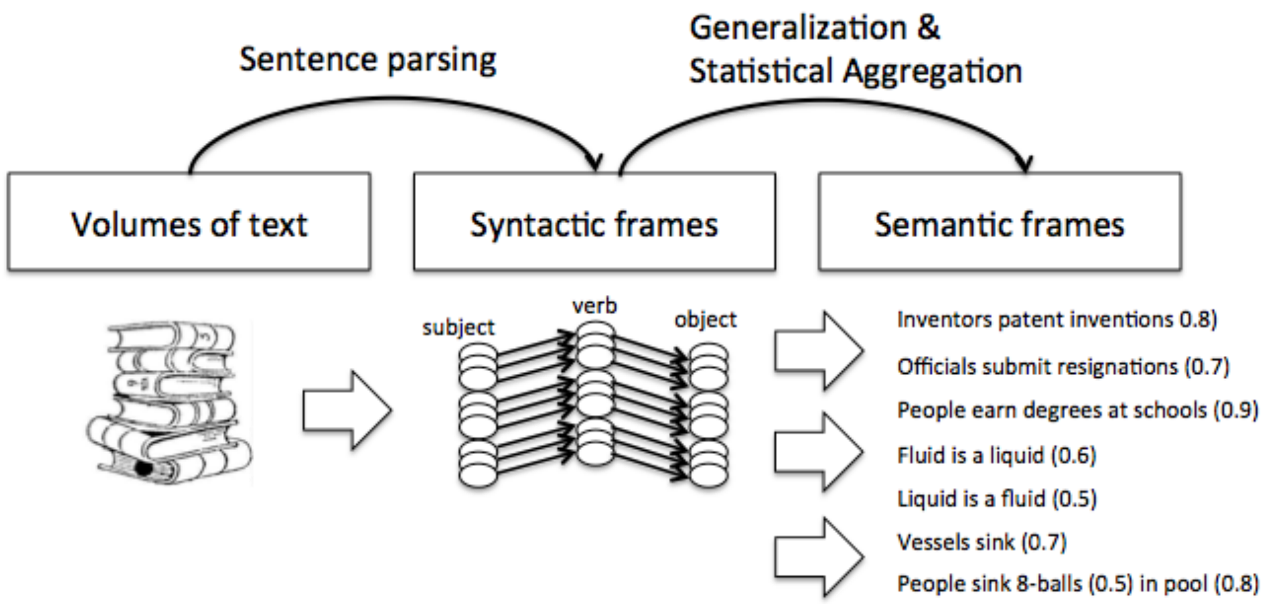

Figure 15 Automatic learning process from reading (IBM Corporation 2010)

Besides learning from volumes of text, DeepQA is capable of learning dynamically within a category. It learns to develop and adjust its confidences in a given category, whether it receives positive or negative feedback. For example, Watson can dynamically learn from the user's responses to its answers that certain question categories might include some other kind of answers candidates that it had previously excluded from that category. Thus, DeepQA is capable of self-assessment by weighing its algorithms with respect to each other and improving them. (Ferrucci 2010)

5.2.5 What Watson is not capable of?

A computer with DeepQA software, such as Watson, can give definite answers to questions and show the confidence level and evidence that it uses to justify an answer. However, it cannot form its own explanations that consist of multiple sentences that describe the ideas in natural language. Explaining is something that requires more complex contextual understanding, producing natural language, and compressing. Even more so, DeepQA is not capable of forming opinions on things, which would require having its own values and goals, more complex knowledge, that is, big picture or systemic thinking, and relevance evaluation, besides capability to explain.

5.3 Putting Watson in perspective

5.3.1 Informed decision-making: Comparison between a search engine and a Q&A expert system

A search engine is capable of retrieving content using keywords as its clue. A question-answering system is capable of doing the same, but in addition to that, it can understand natural language questions and extract precise answer candidates from the retrieved content along with supporting evidence. Web search engines transformed the way people find and access content, but users still had to analyse the content themselves to extract answers and to find evidence to support the answers so as to gain confidence. As a consequence, DeepQA can be a game changer in the way the web search engines were in the 90's and in the turn of the millennium. Figure 16 depicts the distinctions between a search engine and Q&A expert system. (IBM 2011).

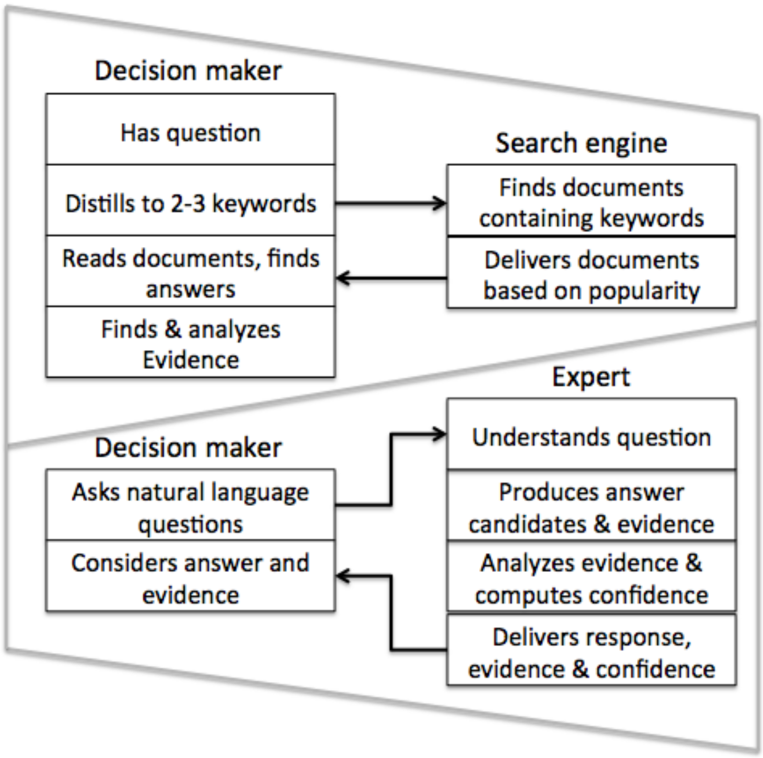

Figure 16 Distinctions between search engines and Q&A expert systems (adopted from IBM 2010)

5.3.2 Comparison between Watson (DeepQA computer) and humans in question answering

To match humans in the capability of answering questions requires understanding questions in natural language, being able to use various hints, broad knowledge, speed, and confidence. Human brain possesses astounding capabilities in all sorts of fields of information processing, including question answering. Surpassing the brains capabilities just in this one field takes enormous amount of computing power and sophisticated parallel technology. (IBM 2011).

The question answering process starts with understanding the question presented. Humans understand questions and what is being asked almost instantly. They know what is important to the questions and how it applies and can use hints, puns, and implications. Watson had to be programmed to go through and analyse a great number of possibilities to get a clue of the relevant meaning, which is challenging because of variability, implicit context, ambiguity of structure and meaning in language. General natural language understanding is the other essential capability in the process, as it is needed for evidence evaluation. Humans understand natural language generally, deeply, and fast and they can read, experience, summarize, and store knowledge in natural language. For Watson, justifying answers happens by going through news articles, dictionaries, reference texts, plays, novels, etc. for answers and evidence. Watson is carefully programmed and trained to deeply analyse even the tiniest subsets of language to return precise answers, not just documents. (IBM 2011).

Self-knowledge or confidence allows knowing, whether one has certainty over an answer or whether it is just an ambiguous hunch. Humans usually know almost instantly how sure they are about an answer. Programming this capability was very challenging as it takes 100's of algorithms that work together to find and analyse 1000's texts for different types of evidence, and then combining the results, scoring and weighing them for their relative evidence. Breadth of knowledge refers to the utilized memory that the knowledge system has. Both humans and Watson are limited by self-contained memory. Some estimates claim that humans have more than 1000 terabytes of memory capacity, which is much higher than Watson's, which adds up to roughly one million books. Human breadth of knowledge is further supported by capability to flexibly understand and summarize human relevance, which means that human's raw input capacity is even higher, although it varies by person. Watson has a weaker ability to meaningfully understand and summarize components that are relevant to humans and lacks full life experience. (IBM 2011).

Processing speed determines how fast a knowledge system can come up with answer candidates, supporting evidence and confidence. Humans, due to relatively instant language abilities, are highly associative and flexible, which help in fast recall, and consequently they grasp the question, find answers, and determine confidence faster. Natural language processing is extremely challenging for computers, which is why Watson was made to use parallel computing to compete against humans in the 3–5 second range. Reaction speed in the case of *Jeopardy,* for example, determines how fast the knowledge system responds to question. Humans have slower raw reaction speed, but determine confidence and answers faster with less effort. Humans can also listen to clues and anticipate while the question is still being uttered, providing them the fastest absolute response times. Watson has an advantage in delivering faster reaction time, only in case it can determine high enough confidence in time to press the buzzer. Watson was not able to anticipate ring-in while listening to clues. In terms of computing power, humans surpass Watson in terms of efficiency. A human brain fits into a shoebox, gets its energy from relatively small amount of food, and has a very efficient cooling system, whereas Watson needs more than 2500 computing cores requiring 80 kilowatts of power and 20 tons of cooling. (IBM 2011).

The two things that Watson surpasses human competence undisputedly are betting and emotions. In betting, humans are slow and less precise, whereas Watson is faster and can perform more accurate calculations. Human performance can also be interfered with emotions that can slow down and confuse processing. Watson is not affected by emotions and thus does not get nervous, tired, upset or psychologically disturbed. (IBM 2011). Comparison between human and Watson's capabilities are presented in Table 11.

Table 11 Comparison between DeepQA (Watson) and humans (adopted from IBM's materials 2010)

	Human	**Watson (programmed by humans)**
Question understanding	**Seemingly effortless:** Almost instantly knows what is being asked, what is important and how it applies—very quickly resolves focus, relevant parts, references, hints, puns, implications, etc.	**Hugely challenging:** Has to be programmed to analyze enormous numbers of possibilities to get just a hint of the relevant meaning. Very difficult due to variability, implicit context, ambiguity of structure and meaning in language.
General language understanding	**Seemingly effortless:** Powerful, general, deep and fast in understanding language—reading, experiencing, summarizing, and storing knowledge in natural language. This information is written for human consumption so reading and understanding what it says is natural for humans.	**Hugely challenging:** Answers need to be determined and justified in natural language sources like news articles, reference texts, plays, novels etc. Watson must be carefully programmed and intensely trained to deeply analyze even just tiny subsets of language effectively. Very different from web search that returns documents containing the question words ranked by popularity. Rather, must find **a precise answer** and understand enough of what it read to if and why a possible answer may be correct.
Self-knowledge (confidence)	**Seemingly effortless:** Most often, and almost instantly, human knows if they know the answer.	**Hugely challenging:** 100's of algorithms are used to find and analyze 1000's of written texts for many different types of evidence, then the results are combined, scored and weighed for their relative importance—how much they justify a candidate answer.
Breadth of knowledge	**Limited by self-contained memory:** Estimates of >1000's of terabytes are all much higher than Watson's memory capacity. Ability to flexibly understand and summarize human relevance (i.e., compress) means that humans' raw input capacity is even higher. But what any person decides to do with their memory varies of course.	**Limited by self-contained memory:** Roughly about 0.5 to 1 million books worth of content memory. Weaker ability to meaningfully understand and summarize human-relevant components. Does not, of course, include a full life experience.
Processing speed	Due to relatively instant language abilities, highly associative, highly flexible memory and speedy recall, generally much faster to grasp question, determine if it knows and to get the answer.	**Hugely challenging:** On one CPU Watson can take over 2 hours to determine if it confidently knows the answer to a typical Jeopardy! question. Watson must be parallelized, perhaps in ways similar to the brain, to use 1000's of compute cores to compete against humans in the 3-5 second range.
Reaction speed	Slower raw reaction speed **but** determines confidence and answer faster and with less effort. Has the ability to listen to clue and **anticipate** when to ring in, providing humans with the fastest absolute possible response time.	More consistently can deliver a fast reaction time, but ONLY IF and WHEN can determine high enough confidence in time to ring-in. Not able to anticipate when to ring-in based on listening to clue, which gives fastest possible response time to humans.
Compute power	Requires one brain that fits in a shoebox, can run on a tuna fish sandwich and be cooled with a hand-held paper fan.	**Hugely challenging:** Needs >2500 computing cores requiring 80Kw of power and 20 tons of cooling (8-10 refrigerators worth in size and space)
Betting	Slower, less precise.	Faster more accurate calculations.
Emotions	Yes. Can slow down and/or confuse processing.	Does NOT get nervous, tired, upset or psyched out.

In sum, Watson had a lot of relative disadvantages compared to human contestants. Despite the relative shortcomings, the developers were able to put together a knowledge system that was finally able to overcome its human rivals with parallel computing utilizing a great number of algorithms and brute power. Moreover, the lack of emotions and consistent and powerful calculation abilities made it a faster and more precise better and unaffected by emotions or pressure.

5.3.3 *The Jeopardy Challenge* as a stage for metrics of performance

The *Jeopardy Challenge* provided IBM's research team a captivating and illustrious way to drive and measure the DeepQA technology in automatic open domain question answering. There were five dimensions along with the technology was tested, including breadth of domain, high precision, accurate confidence determination, complex language, and speed. (Ferrucci et. al 2010)

The five dimensions are described below:

1. **Breadth of domain**

   Jeopardy game show questions cover all kinds of domains of knowledge from history to science, from popular music to classical literature.

2. **High precision**

   In *Jeopardy,* answering questions is one thing, but getting the answers right is another. Getting questions wrong results in losing the dollar value associated with them. Precision measures the ratio of how many answers are right out of all the questions answered.

3. **Accurate confidence determination**

   Confidence is the probability the system determines for itself of being right. Accurate confidence determination means the system gets on average as many questions right as its confidence level estimates. An accurate confidence of 95% means the system gets 95 questions right out of 100.

4. **Complex language**

   In *Jeopardy*, the questions are richly formulated and include a broad spectrum of grammatical structures and peculiar expressions used to refer to a large range of things and their properties. The questions include jokes, metaphors, puns, irony, riddles, and wordplays.

5. **Speed**

To compete in *Jeopardy* it takes speed to formulate an answer. The contestants, including Watson, had to wait until the Host, Alex Trebek, had read the question in its entirety, before they could hit the buzzer button. For Watson, the clues were presented in electronic texts at the same time they became visible to the human contestants. In general, it took a few seconds for Trebek to finish reading the question, which was the time the contestants had to think for the answer. Watson used this time to determine, whether if was confident enough to press the buzzer button.

5.4 The technology behind Watson

5.4.1 Architecture

> *"Watson is a good demonstration that the whole is greater than the sum of its parts. Like a human, it uses multiple strategies and sources of knowledge in order to come up with not just an answer, but the best answer."* —Susan Feldman (2011)

According to the IBM's DeepQA project homepage (2012), Watson is an application to the discipline of open-domain question answering that consists of leading-edge technologies in *Natural Language Processing, Information Retrieval, Knowledge Representation and Reasoning,* and *Machine Learning*. The central technology behind Watson is software called DeepQA that runs on Linux. DeepQA "is a massively parallel probabilistic evidence-based architecture" (Ferrucci et al. 2010, 68). It is designed for *hypotheses generation, massive evidence gathering, analysis,* and *scoring.* (Ferrucci et al. 2010) Here, the term "*massive parallelism"* means that the system makes use of numerous interpretations and hypotheses simultaneously side by side.

Watson is not based on any single can-do-it-all-algorithm, but many that are working in parallel. For instance, in the context of *Jeopardy*, Watson was using more than 100 different techniques for analyzing natural language, identifying sources, finding and generating hypotheses, finding and scoring evidence, and merging and ranking hypotheses. The most important technological advancement in Watson is how all these separate algorithms work together as a whole, so as to make these different overlapping approaches bring their strengths in contributing to providing an answer in terms of accuracy, precision, and speed. (Ferrucci et al. 2010)

5.3.2 Hardware

According to an article at University of Maryland's website (2011), Watson is a workload optimized and parallel computing system consisting of thousands of processors designed for complex analytics. Depending on the hardware, it is potentially able to answer natural language questions in less than three seconds, which is made possible by integrating massively parallel POWER7 processors and the IBM DeepQA software. Watson is made of a bundle of ninety IBM Power 750 servers, totalling 2880 POWER7 processor cores and 16 terabytes of RAM. In each Power 750 server there is a 3.5 GHz POWER7 eight-core processor, with four threads in each core. The processing capability of the POWER7 processors matches ideally Watson's DeepQA software, which is *embarrassingly parallel,* that is, it executes multiple threads simultaneously. As a comparison, one *Jeopardy* question can take 2 hours on a single typical 2.6 GHz core found in consumer computers, which means that Watson with its hardware is approximately 2400 times faster. According to an interview with Ferrucci in Daily Finance (2011), Watson can process 500 gigabytes of information a second, which is equivalent to approximately a million books. IBM's master inventor and senior consultant, Tony Pearson, evaluated Watson's hardware, 90 units of Power 750 servers, to cost around $3 million in 2011.

5.4.3 Data

Watson can be connected to the Internet, but can also rely entirely on the data that is loaded to its knowledge base. In the *Jeopardy challenge,* for instance, its reference data totalled some 15 terabytes of disk storage, as the game covers stacks of different kind of questions in a very broad domain. In the game, Watson's sources included a comprehensive array of dictionaries, thesauri, newswire articles, literary works (such as plays, novels, and bibles), and encyclopaedias, including the full text of Wikipedia. Along with the content for the answer and evidence sources, the DeepQA software inside Watson utilized other types of semi-structured and structured content, which include databases, taxonomies, and ontologies. (Ferrucci et. al 2010)

5.4.4 Operation

As mentioned before, DeepQA is a massively parallel, probabilistic, evidence-base architecture. Interpreting natural language questions and producing an accurate answer has many steps in between that mostly take place simultaneously. The high-level architecture of DeepQA is depicted in figure 17:

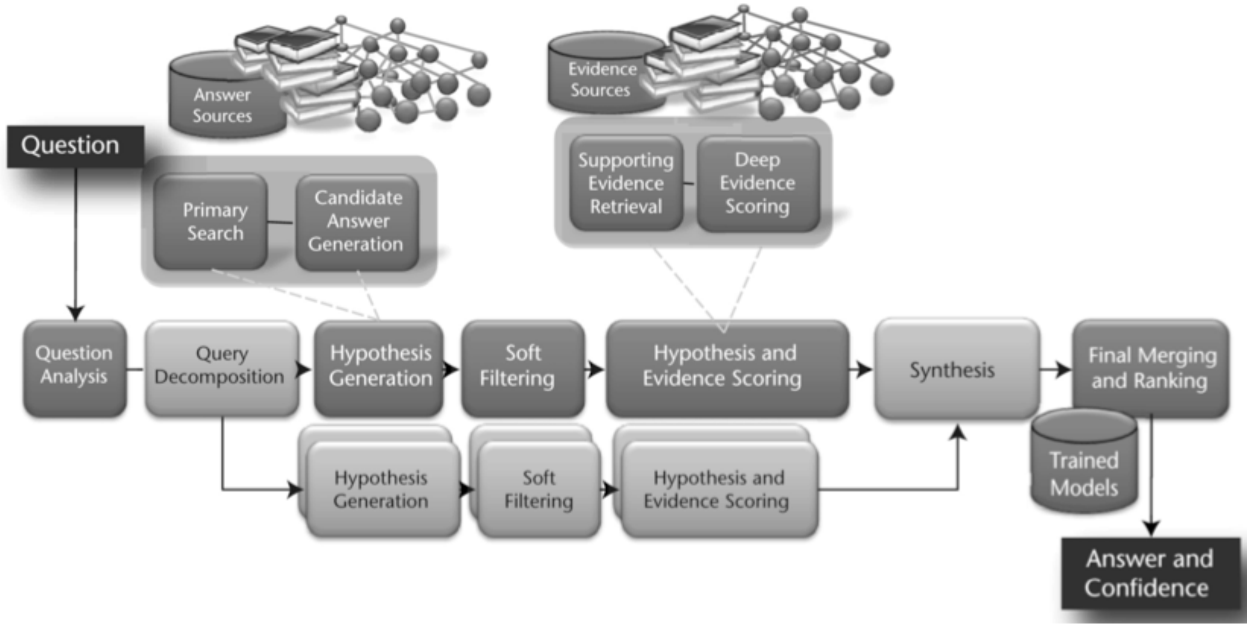

Figure 17 DeepQA High-Level Architecture (Ferrucci et al. 2010)

When Watson receives a question, it parses the question and generates many different queries to search its knowledge base in parallel. Each query, or hypotheses returns answer candidates, for which Watson then gathers thousands pieces of evidence. Next a combination of algorithms starts to analyse the evidence, compute confidence scores, and finally rank the answers and confidence scores. The highest scoring hypothesis wins. (Ferrucci 2010; Feldman 2011) At the same time, machine-learning applications called *learn models* make it possible for Watson to do self-assessment. The system learns how to weigh the different language analyzing techniques with respect to each other, and ultimately starts to refine them. (Ferrucci, 2010)

5.5 Synopsis of Watson's capabilities

From the information presented above I go on to construct a simplified model of the technology at hand. DeepQA enables creating machines, which are fundamentally capable of having a simple questions-answering dialogue with a human user through a chat or speech to help extract answers from given material and at the same time learn in the process, that is, build knowledge on how things are linked to one another and how to serve the user better.

In synopsis, Watson is a technology that has three key capabilities that are enabled by the sophisticated DeepQA software. The three key capabilities include:

- Capability to answer questions using source material
- Capability to increase confidence by posing the user simple clarifying questions in order to bring more accuracy and relevance to the answers. Together with the previous property forms an ability to have a simple dialogue between a user and itself.
- Capability to learn and improve answers and question so as to provide more relevant answers to the user over time.

The previous capabilities are presented more precisely in Table 12.

Table 12 DeepQA computer capabilities

Gives simple answers to natural language questions	Analyses large volumes of structured, semi-structured and unstructured data
	Interprets and understands natural language questions
	Generates and evaluates hypotheses and quantifies confidence in answers
Supports iterative dialogue to refine results	Identifies gaps and uncertainties in knowledge
	Presents questions in simple language to fill gaps in knowledge and increase confidence
Adapts and learns to improve results over time	Recognizes patterns
	Alters concepts and categories

To form a better understanding of the capabilities of a DeepQA-run computer like Watson, one can approach the matter from the perspective of a librarian's work. For example, a person might need information to make a more educated decision and goes to a library. He or she arrives at the counter, where there are two librarians. The first librarian possesses the same capabilities as a web search engine. To the first librarian, the questioner gives key words. The first librarian then goes through all the books in the library, underlines all the spots where the key words appear and presents to the person all the books that contain the keywords in the order of how known the books are, how close together the words appear, and/or how recent the books are. After that, the knowledge worker turns to the second librarian and instead of presenting him or her just keywords, the questioner poses a question in natural language. The librarian then goes to read all the books in the library that might have answers, finds answers candidates in the books, evaluates the evidence for the answers and presents the person with a sheet of paper consisting of the most probable answer candidates and telling how confident he or she is of the correctness of each of the answer candidates. If the questioner wants to know how the librarian ended up with the answers, the librarian justifies his or her answers with evidence that he or she found in the books. The latter librarian, thus, more cognitive tasks that are also of higher order, thus saving time and energy for the questioner.

5.6 Business applications of Watson

According to both IBM's training materials (2010) and IBM's general manager of Watson Solutions, Manoj Saxena (2011), the company is currently developing business applications for Watson in healthcare, tech support, finance, enterprise knowledge management and business intelligence, and government services. According to Weber (2011), Watson could also be of help in legal research.

Thus far, the strongest focus has been on healthcare where IBM has already partnered with Nuance communication, Wellpoint, GE, University of Maryland, Maine Center for Cancer Medicine and Westmed Medical Group in New York to exploit Watson's capabilities in clinical decision support systems. According to IBM's website, the collection of medical information available is increasing twofold every fiver years and most of the data is unstructured, mostly in natural language. Doctors lack the time to look through journals to keep informed of the latest developments. To tackle this problem, Watson could be used to provide help diagnosing and treating patients using vast bodies of information. In the first stage, the doctor poses queries to Watson, naming symptoms and other related information. Watson, then, utilizes its natural language processing capability to mine through the patient information to find relevant facts about family history, current medications and other health information. Next, it combines this information with present finding from tests to formulate hypotheses and test them. Lastly, it presents the most likely diagnoses with related evidence and levels of confidence.

According to IBM's website (2013), Watson can also be applied in finance. IBM is currently partnering with financial institutions to teach Watson about the workings of retail and institutional banking. Financial service companies have to deal with hugely complex information challenges. For example, financial service professionals receive hundreds of emails per day and Wall Street analysts produce five research documents every minute. Watson's capability to go through vast bodies of information and data to recognize patterns and form evidence-based hypotheses makes it an excellent aid in making informed decisions on investment choices, trading patterns and risk management.

Eventually, as Watson's price drops and availability increases, it could prove useful for consumers as well. Among them is assisting consumers in making better purchase decisions. In today's world of global market and digital communication, consumers face a myriad of alternatives when looking for the best deals, whether it be finding mobile telephone subscriptions, hotels, laptops, automobiles, or real estate that meet their needs. Watson could go through thousands of alternatives and analyse them in terms of the values that the user appreciates the most. It would level the information asymmetry in the market and foster more competition, as consumers would no longer resort to the alternatives and brands that are advertised the most. Watson could also be used to spot questionable terms and conditions.

6 ANALYSIS OF THE KNOWLEDGE WORK JOBS AND WATSON

In this Chapter, I shall examine the five knowledge work jobs further and use the newly constructed framework laid out in the fourth Chapter as a lens to analyse the empirical material. First, I strive to identify what tasks are the roles of the knowledge workers jobs consisting of, after which I go on to formulate task types from the tasks and task categories from the task types. Then, I reflect what knowledge capabilities are required to perform the tasks types. After that, I analyse what knowledge capabilities Watson possesses. Finally, I analyse how largely its knowledge capabilities cover the required knowledge capabilities in the task types.

6.1 Knowledge work jobs and their tasks

6.1.1 Dismantling the roles into tasks in the five knowledge work jobs

This part of my analysis examines the roles of the five knowledge workers presented in the previous Chapters. I shall identify what tasks the roles are composed of. After that, I shall briefly describe each task and analyse what capabilities are required to perform them. In the capability analysis, my approach is to reflect what would be the minimum level of capabilities to perform each task in terms of the amount of sophistication of capabilities. For example, if a task can be performed with producing simple language, which is a lower-level capability compared to producing natural language, then producing natural language will not be included into the required capabilities, since the task can be performed by producing simple language alone. The capability analyses for each individual task can be found in Appendix 1, where as the synopsis for each job is presented in tables in Chapter 6.1.

Amadeus, user operations associate at Trendster Inc.

Amadeus's job as a user operations associate is divided into six roles, some of which are consisted of more routine-like tasks such as direct user support person for Finnish companies, and others comprise of more non-routine tasks like the role of developer of the automated user self-service system. Altogether eighteen tasks were identified through the analysis of the roles. The job, roles and the tasks are presented in Table 13.

Table 13 The roles and their tasks of Amadeus's user operations associate job

Job	Roles	Tasks
User operations associate	**Developer of the automated user self-service system**	Recognizing patterns in user data
		Using statistics to verify hypotheses
		Making changes in the system
		Testing the system
	Localization person	Checking language translations
		Generating solutions for back-up systems
	Member of Site	Hypothesizing causes of problems
		Answering technical questions
	Direct user support	Verifying document authenticity
		Answering technical questions
	Contact person	Answering questions
		Asking questions for another party
		Explaining issues
		Delegating customer problems
	Job applicant evaluator	Visual analysis of job applicants
		Asking job applicants questions
		Directing discussion in job interviews
		Evaluating and deciding over job applicants

Arnold, project manager at NEOT

Arnold's job as a project manager consists of six roles in which I identified 23 tasks altogether. His job roles are almost completely non-routine. The job, roles and the tasks are presented in Table 14.

Table 14 The roles and their tasks of Arnold's project manager job

Job	Roles	Tasks
Project manager	**Planner and organiser of tender preparation**	Gathering relevant information from databases
		Devising stipulations for tender
		Compiling a formal tendering document
		Sending tendering document to firms
		Gathering and organising bids
	Industry investigator	Interviewing industry experts
		Drawing conclusions for the redesign of transportation
	Member of development workshops	Generating solution alternatives
		Evaluating the impact of solution alternatives on customers
		Asking questions
		Explaining NEOT's situation and its goals
		Convincing the other party
		Preparing PowerPoint presentations
	Data and operations analyst	Recognizing improvement potential by looking at data
		Generating solution alternatives to exploit improvement potential
	Manager of the IT project system specifications	Explaining NEOT's needs
		Generating specification alternatives
		Asking questions about feasibility
		Evaluating specification alternatives
	IT project coordinator	Requesting information from project members
		Disseminating project information
		Delegating tasks
		Organizing schedules

Barney, automation engineer at Metso Corp.

Barney's job as an automation engineer includes seven roles in which I identified 26 tasks overall. His job roles are both routine, like being a technical support person, and non-routine such as being a designer of automation specification. The job, roles, and tasks are presented in Table 15:

Table 15 The roles and their tasks of Barney's automation engineer job

Job	Roles	Tasks
Automation engineer	**Designer of automation specifications**	Generating automation solutions that fulfil requirements
		Writing documents that describe automation specification for programmers
		Calling for bids from subcontractors
		Deciding over bids and having them approved by supervisor
	Requirement specifications informant	Gathering specification information relevant to automation from meetings
		Explaining automation's limitations
		Discussing technical details face-to-face
		Deciding over technical details in face-to-face discussion
		Looking at diagrams to gain understanding
	Support person for programmers	Explaining in other words about specifications
		Evaluating whether specifications can be modified in a certain way
	Technical support person	Answering technical questions
		Observing machines to find solutions to technical problems
		Hypothesizing solutions to technical problems
	Tester of automation	Operating the testing device
		Evaluating the functioning of technical features
	Project manager	Evaluating, monitoring and recording costs
		Checking and approving invoices
		Asking subcontractors about details regarding to various figures
		Prompting subcontractors
	Observer of machines at worksites	Operating machines
		Observing machines' functioning
		Writing reports based on observations

Huckleberry, customer service associate at Infotron Inc.

Huckleberry's job as a customer service associate includes four roles in which I pinpointed sixteen tasks altogether. His job has some resemblance to Amadeus's job and has relatively many routine elements, like being a customer service person, but also clearly non-routine roles such as being a member of market trend analysis project. The job with its roles and tasks is presented in Table 16:

Table 16 The roles and their tasks of Huckleberry's customer service associate job

Job	Roles	Tasks
Customer service associate	**Customer service person**	Answering questions
		Escalating problems to other teams
		Hypothesizing causes of problems
		Generating solution alternatives to problems
	Contact person between customer service and regional marketing teams	Answering questions
		Asking questions for another party
		Explaining processes
	Member of company support centre development project	Generating development ideas based on experience
		Using analyzing tools to build understanding on customers
		Explaining ideas and knowledge from the customer perspective in meetings
		Evaluating development ideas
	Member of market trend analysis project	Recognizing patterns from data and information
		Hypothesizing causes behind trends
		Writing reports
		Gathering ideas and information from meetings
		Explaining ideas and knowledge in meetings

Wulle, societal relations associate at Businessor Inc.

Wulle's job as a societal relations associate includes four roles in which I identified 24 tasks all in all. The job has more emphasis towards non-routine knowledge work like in the event organiser, meetings attendant and coordinator, and project member and coordinator roles. Only the financial administrator role leans clearly on the routine work side. The job with its roles and tasks is presented in Table 17:

Table 17 The roles and their tasks of Wulle's social relations associate job

Job	Roles	Tasks
Societal relations associate	**Event organiser**	Generating event topic alternatives
		Scheduling and making arrangements with student organisations
		Making premise reservation
		Prompting
		Choosing relevant speakers
		Handling sudden problems
	Meetings attendant and coordinator	Gathering information
		Writing down agreements
		Explaining what has been done and how
		Summing up discussion
		Directing discussion on project management practicalities
	Project member and coordinator	Preparing agendas
		Creating project plans
		Conducting investigation on unclear subjects
		Getting information from project members
		Compiling project information and sending it to members
		Monitoring project schedules
	Financial administrator	Making budget forecasts
		Monitoring actual costs
		Preparing invoices for managers to be approved
		Making transactions
		Prompting managers to approve invoices
		Requesting extra funds when noticing a need
		Filling forms to prevent bribery accusations

6.1.2 Formulation of task types and categories from the knowledge work tasks

In this part of my analysis, I went through all the tasks of the five knowledge workers and identified common characteristics in the tasks for the purpose of forming meaningful task types. From the task types I then formed task categories. As a result, I formed altogether 25 task types from the 104 tasks that were identified in the job roles of the five knowledge workers. I then grouped the 25 task types into four task categories: communicative tasks, analytical tasks, synthetical tasks, and operative tasks, and classified the categories into two task classes: internal tasks and external tasks. As a justification for forming a task type, I used the uniqueness of the task, whether or not the task type would consist more than one task. I have presented each task under their task type in the appendix.

In figure 18, the division of tasks types is presented. The first division is into internal and external tasks, where the internal tasks are those that knowledge workers do mainly independently and external tasks are those that essentially involve being in contact with other people or systems that affect other people or systems. External tasks are tasks where the value of knowledge work is delivered. The internal tasks are further divided into categories of analytical and synthetical tasks, and the external tasks to categories of communicative and operative.

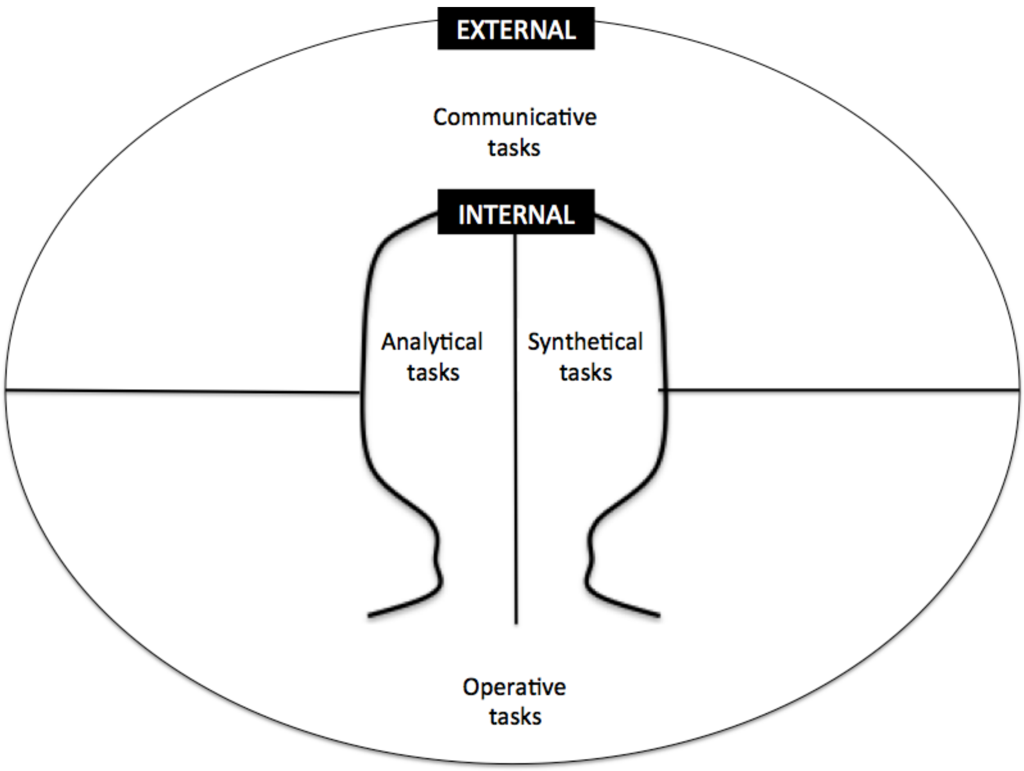

Figure 18 Division and categories of knowledge work tasks

Below, I present the task types that I identified with descriptions that I identified. The number of tasks belonging to them is found in the brackets.

INTERNAL: Analytical tasks

Analytical tasks are tasks, whose purpose is to refine and deem information for some further use by using knowledge and mostly analytical knowledge capabilities. The results of analytical tasks can then be used for synthesizing knowledge, deepening understanding on things, decision-making, doing operations, etc. In this framework, analytical tasks include also those tasks, whose end result appear not only inside the knowledge workers mind, but can also manifest as an collection of data or information on paper or computer that has been accomplished via analytical thinking and the use of some analytical tools and/or computer software.

Checking and approving / disapproving (3 tasks): The act of analyzing, whether a unit or compilation of information has certain characteristics and then deeming it accordingly. This is a basic task in, e.g., organisational bureaucracy.

Investigating (1 task): The act of searching for information from various sources to gain certainty on various issues that need to be clarified in order to, for example, make more sound decisions or to obtain a more profound understanding over a given matter. Requires knowledge on where to look for information, be it human informant, digital databases, or written documents or books, and also understanding what kind of information is missing.

Gathering data and information (6 tasks): The act of exploring various information sources and assembling data and information that has certain attributes.

Monitoring (2 tasks): The act of periodically or constantly keeping oneself up-to date about selected topics (Reinhardt et al., 2011) or some observable objects to gain information and finding out, whether or not anything meaningful has occurred.

Recognizing patterns and possibilities (3 tasks): The act of scanning and processing data and information and noticing some order or repetitiveness in it that can be relevant to a higher task or goal of the knowledge agent.

Scheduling (2 tasks): According to Mintzberg (2009), scheduling is the act of slicing up various concerns into distinct tasks, to be carried out in specific slots of time.

Testing programs (1 task): The act of operating and trying various features of computer programs and at the same time assessing, whether or not the program works as supposed to. Includes also registering other essential appearing issues.

Using analyzing tools to create information and insights (2 tasks): The act of operating various software programs to analyse information to create new, more applicable information and deeper understanding of entities and workings of a particular domain.

Visual analysis (4 tasks): The act of visually observing documents, pictures, videos, or some other visual objects to detect various predetermined or unspecified relevant characteristics in them.

INTERNAL: Synthetical tasks

Synthetical tasks are tasks that involve creativity, high-level evaluation, and high-level decision-making. The end results of these tasks are, for example, ideas, solution alternatives, models, perspectives, visions, pieces of art, and decisions inside the mind of a knowledge worker. In this framework, synthetical tasks include also those tasks, whose end result appears not only inside the knowledge workers mind, but could also manifest as a picture, audio file, drawing, outline, framework etc. on paper, as an object or on a computer file.

Evaluating and deciding (11 tasks): The act of assessing holistically, whether an idea, alternative solution or some other observable object serves the values and goals of the unit or organisation in a given situation, and then making a decision on the issue and stating that decision. Differs from analysis in the sense that it is not restricted merely on utilizing some rigid, technical framework, but instead takes numerous other factors in account such as strategy, culture, politics and various human factors. Among humans often incorporates what is called common sense and intuition.

Generating ideas and alternative solutions (11 tasks): The act of synthesizing new configurations of knowledge that might potentially have the characteristics in offering a solution to a given situation or problem. The act may also consist of turning that synthesized knowledge into communicable information such as speech, text, documents etc.

Hypothesizing (4 tasks): The act of synthesizing and inferring knowledge to postulate probable causes for various phenomena, namely problems and successes.

EXTERNAL: Communicative tasks

Communicative tasks involve tasks, whose purpose is to receive information from and disseminate information to other people via written text, spoken language, and gesturing. It also involves processing that information and evaluating and deciding what information to share with whom.

Answering questions (7 tasks): The act of interpreting questions presented in natural language and providing verbal or written answers to them by using knowledge bases and inferring.

Delegating (3 tasks): The act of identifying and evaluating, which knowledge agents are the most appropriate bearers of a certain area of responsibility in a given situation, choosing them, and conveying a request or command to them to take on the responsibility.

Directing discussion (2 task): The act of communicating and gesturing in such a way amidst a meeting so as to guide the discussion of the participants to address relevant issues and thus facilitating decision-making among other things.

Discussing and deciding together (2 tasks): The act of receiving and transmitting information by listening, watching, speaking and gesturing or reading and writing in a real time situation to address relevant issues for the purpose of eventually coming into a conclusion with the other party and reaching a common decision.

Information disseminating (2 tasks): The act of choosing appropriate recipients and information that is relevant to them, packaging it into a fitting form and conveying it in a situation.

Explaining knowledge (14 tasks): The act of turning knowledge into information that is understandable for the recipient. Includes writing text, speaking and gesturing. In the act it is essential to choose what details to explain and what to leave out to make the explanation appropriate length for the receiver. Moreover, the order, form, and type of language are of importance.

Persuading and negotiating (2 tasks): The act of convincing and attempting to get another party to provide with resources using written or spoken language and gesturing and at the same time following the other party's reactions.

Prompting people (3 tasks): The act of assessing, whether enough time has passed without getting a desired outcome from a knowledge agent and then forming a message or carrying a conversation to remind or command the knowledge agent to have the desired outcome delivered faster.

Requesting information (9 tasks): The act of assessing what information is valuable in a given situation and then forming an appropriate verbal request or carrying a conversation in order to make the informant provide with enough relevant information.

EXTERNAL: Operative tasks

Operative tasks are tasks that involve doing actions in one's environment to cause changes in it, like moving something or making changes in some system, or putting something together like documents.

Handling sudden problems / fire fighting (1 task): The act of reacting swiftly to a sudden, unexpected problem by various means and often without any existing protocol. Can involve basically engaging in any of the task types and switching between them dynamically to correct the situation.

Making changes in systems (3 tasks): The act of altering settings, configurations or the state of some information system via a computer and computer programs.

Operating machines (2 tasks): The act of controlling or altering a machine using physical means such as limbs, hands or other physical extensions.

Compiling documents (4 tasks): The act of producing an easy-to-use corpus of information by gathering and organising information into a certain order and form. The tasks under this category also consist of choosing what information to present and what to leave out.

It goes without saying that no knowledge task belongs purely into just one category. Obviously, nearly all tasks have characteristics of the other task categories. For example, I have put the compiling documents task type into operative tasks, despite the fact that compiling documents naturally involves, e.g., analyzing what sort of information the users of that document need and in what form, and also coming up with ideas and solution alternatives of how to put the content together in such way that satisfies the user. Furthermore, many of the analyzing tasks are made using a computer program, which means that the knowledge worker is not doing the task entirely internally in his or her mind, because one is doing (operating) something with a computer. Thus, I see that the task categories serve as a guide in grasping what the end result of a task is. If the end result of a given task is for a knowledge worker's independent use to serve one in some further task that is later on going to involve external tasks, then those tasks can well be categorized as internal tasks.

6.2 Analysis of the required knowledge capabilities in the knowledge work task types

Using the framework of knowledge agent's knowledge capabilities as a lens, I shall next reflect what knowledge capabilities are required in the tasks types and categories that were identified and formed from the tasks in the jobs of the knowledge workers. I first analysed the required capabilities of all the knowledge work tasks separately and then using that information, I placed the required capabilities for each task type. After that, I did the same thing for knowledge work task categories by putting together the required capabilities of the task types.

INTERNAL: Analytical tasks

Checking and approving / disapproving (3 tasks):

- Perception to take in visual signals or textual information
- Receiving data to take in textual information in a digital form
- Interpreting visual information to form a visual overview of documents and to check their authenticity
- Interpreting natural language to associate text with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values, goals, rules, regulations etc. of the company and unit that are related to documents and of various characteristics to evaluate their authenticity among other things
- Semantic analysis to find out, whether objects or documents under analysis has certain attributes or not

- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Producing natural language to write information and justifications in documents' fields
- Operating computer programs to access systems, data and information to find relevant data and information in the organisation's database and to approve/disapprove
- Communication to externalize information

Investigating (1 task):

- Perception to take in textual and numerical information (alternatively can operate through receiving data)
- Receiving data to take in textual information in a digital form
- Recognizing patterns in data and information to get insights and find meaningful associations to relevant knowledge
- Interpreting natural language to associate text or speech with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Semantic analysis of the found material and information to find out, whether the issue under investigation has certain qualities
- Categorizing put data and information into reasonable information structure and to create a structure for the possible report of the investigation
- Evaluating evidence evaluating evidence to evaluate probability and confidence of facts
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to determine from time to time how to continue with the investigation
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Producing natural language to write down findings in documents

- Operating computer programs to get access to data and information
- Communication to externalize information

Gathering data and information (6 tasks):

- Perception to take in textual and numerical information (alternatively can operate through receiving data)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting natural language to associate text with relevant knowledge
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Relevance evaluation to guide focus and tell important information and knowledge apart from less important in terms of serving values
- Categorizing to put data and information into reasonable information structure
- Evaluating evidence to evaluate probability and confidence of facts
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to determine from time to time how to continue with the gathering
- Operating computer programs to get access to data and information
- Communication to externalize information

Monitoring (2 tasks):

- Perception to take in textual and numerical information (alternatively can operate through receiving data)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information to associate visual data, such as charts, pictures, videos, live situations with relevant knowledge
- Interpreting natural language to associate text or numerical data in information sources to relevant knowledge
- Learning to improve the utilization of the knowledge capabilities in performing the task

- Knowledge of situation and the object under monitoring and the values and goals of the company and unit
- Structured knowledge of the elements that are to be monitored, such as time and various figures
- Relevance evaluation to guide focus and tell important information and knowledge apart from less important in terms of serving values
- Operating computer programs to get access to data and information that is to be monitored
- Communication to externalize information

Recognizing patterns and possibilities (3 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information to associate visual data, such as charts, pictures, videos, live situations with relevant knowledge
- Interpreting natural language to associate text or numerical data in information sources to relevant knowledge
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Recognizing patterns in data and information to get insights and find meaningful associations to relevant knowledge
- Knowledge of the values and goals of the company and unit
- Relevance evaluation to guide focus and tell important information and knowledge apart from less important in terms of serving values
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Operating computer programs to get access to data and information to be examined
- Communication to give commands to computers

Scheduling (2 tasks):

- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values, goals, situation and resources of the company and unit
- Structured knowledge of time and task characteristics
- Relevance evaluation to guide decision-making and tell important information and knowledge apart from less important in terms of serving values
- Semantic analysis of tasks to get an idea how much time and effort they require
- Categorizing to find a reasonable way to group tasks together
- Inference to derive relevant logical conclusions about the tasks and time to get a better comprehension of the situation and to evaluate their relevance
- Operating computer programs to enter information into the schedule and to get access to data and information
- Communication to externalize information in the schedule

Testing programs (1 task):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information to evaluate the look and feel of interfaces and features of computer programs and websites
- Interpreting natural language to associate text with relevant knowledge
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the programs and what they are supposed to be like
- Semantic analysis of various program features and their functionality to evaluate their relevance
- Relevance evaluation to guide focus and tell important information apart from less important in terms of serving values
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Operating computer programs to get access to the program, data and information

- Communication to externalize information to a report, for example

Using analyzing tools to create information and insights (2 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data)
- Receiving data to take in textual and numerical information in a digital form
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of how to use the material and data at hand and the analyzing tool, and of the values and goals of the company and unit
- Semantic analysis of the material and data at hand on a general level to know how to apply the analyzing tool
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Operating computer programs to get access to the analyzing tool, data and information
- Communication to give commands to computers

Visual analysis (4 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Interpreting visual information of various objects and their characteristics that are under analysis to produce information for semantic analysis
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Semantic analysis to further refine knowledge of the visual observations and analysis
- Categorizing to label and group visual observations in reasonable way
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance

INTERNAL: Synthetical tasks

Evaluating and deciding (11 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information of information objects
- Interpreting natural language to associate text and speech with relevant knowledge
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Relevance evaluation to guide evaluation and decision-making and tell important information and knowledge apart from less important in terms of serving values
- Semantic analysis of the object/alternative and its features under analysis to evaluate the its relevance
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to periodically determine how to continue with evaluation and decision process in order to serve the desired values
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Synthesizing knowledge to come up with solutions and decisions with certain parameters in mind

Generating ideas and alternative solutions (11 tasks):

- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Relevance evaluation to guide decision-making and tell important information and knowledge apart from less important in terms of serving values
- Categorizing to put data and information into reasonable information structure
- Goal formulation to periodically determine how to continue with idea and alternative solution generation process in order to serve the desired values
- Synthesizing knowledge to come up with new solutions alternatives with certain parameters in mind
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance

Hypothesizing (4 tasks):

- Learning to improve the utilization of the knowledge capabilities in performing the task
- Recognizing patterns in data and information to get insights and find meaningful associations to relevant knowledge
- Knowledge of the phenomena
- Semantic analysis of the elements of the phenomena to grasp a better understanding of the problem
- Categorizing to put data and information into reasonable information structure
- Synthesizing knowledge to find new potential causes for problems
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance

EXTERNAL: Communicative tasks

Answering questions (7 tasks):

- Perception to take in verbal or textual information (alternatively can operate through receiving data)
- Receiving data to take in textual information
- Interpreting natural language to associate text and speech with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Semantic analysis of the source material to discern its elements and characteristics to help evaluating evidence and confidence
- Evaluating evidence to evaluate probability and confidence of answers and their supporting facts
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Producing simple language to express answers
- Communication to externalize information

Delegating (3 tasks):

- Interpreting natural language to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Structured knowledge of time, people's positions and expertise, and task types
- Semantic analysis of tasks to get an idea how much time and effort they require and of the resources and capabilities of different workers to evaluate their suitability to take on various tasks
- Relevance evaluation to guide decision-making in delegation and tell important information and knowledge apart from less important in terms of serving values

- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Categorizing to put data and information into reasonable information structure
- Producing natural language to tell about the appointees about their election and to explain about their responsibility
- Communication to give commands and explanations

Directing discussion (2 task):

- Perception to take in visual and auditory signals and verbal information produced by the participants
- Interpreting natural language to associate speech with relevant knowledge and to produce natural language
- Interpreting visual information to observe the situation and non-verbal reactions of participants
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Relevance evaluation to tell important information and knowledge apart from less important in terms of serving goals and values of the discussion
- Goal formulation to periodically determine how to continue with the discussion to reach desired values
- Categorizing to put data and information into reasonable information structure
- Producing natural language to communicate to the participants and tell them to change subjects
- Gesturing to communicate non-verbally with the participants and direct them
- Communication to externalize information
- Physical action to make gestures that facilitate getting the point across

Discussing and deciding together (2 tasks):

- Perception to take in visual and auditory signals and verbal information produced by the participants
- Interpreting natural language to associate text and speech with relevant knowledge and to produce natural language

- Interpreting visual information to observe the situation and non-verbal reactions of participants
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the values and goals of the company and unit
- Categorizing to put data and information into reasonable information structure
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to periodically determine how to continue with the discussion and decision process to reach desired values
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Categorizing to put data and information into reasonable information structure
- Producing natural language to express knowledge, opinions, and proposals in speech
- Gesturing to communicate non-verbally with the other party and direct them to express attitudes
- Communication to externalize information
- Physical action to make gestures that facilitate getting the point across

Information disseminating (2 tasks):

- Interpreting natural language to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Structured knowledge of people's positions, authorization and expertise
- Categorizing to put data and information into reasonable information structure
- Producing simple language to tell the recipient about the topic of the information and other formalities
- Communication to externalize information

Explaining knowledge (14 tasks):

- Interpreting natural language to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the subject and of the values and goals of the company and unit
- Categorizing to put data, information, and knowledge into reasonable information structure
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to periodically determine how to continue with the explanation process to reach desired values
- Producing natural language to explain knowledge in written text or speech
- Communication to externalize information

Persuading and negotiating (2 tasks):

- Perception to take in visual signals and verbal data of the opposite party
- Interpreting natural language to associate text and speech with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the other party's values and goals and of the values and goals of the company and unit
- Relevance evaluation to tell important information and knowledge apart from less important in terms of serving goals and values of the discussion
- Producing natural language to influence the other party and express requests in written text or speech
- Gesturing to help the other party becoming convinced
- Communication to externalize information
- Physical action to make gestures that facilitate getting the point across

Prompting people (3 tasks):

- Learning to improve the utilization of the knowledge capabilities in performing the task
- Relevance evaluation to tell important information and knowledge apart from less important in terms of serving goals and values of the discussion
- Structured knowledge of time, people's positions and responsibilities
- Producing simple language to express simply about the need to get something done and other formalities
- Gesturing to express attitude and desire to get something done the other party
- Communication to externalize information
- Physical action to make gestures

Requesting information (9 tasks):

- Interpreting natural language to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the issue, the other party, and of the values and goals of the company and unit
- Relevance evaluation to tell important information and knowledge apart from less important in terms of serving goals and values of the discussion
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Producing simple language to express the request for certain information and other formalities
- Communication to convey the request

EXTERNAL: Operative tasks

Handling sudden problems / fire fighting (1 task):

- Perception to take in visual signals and verbal, textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information of the various elements in the surrounding to produce information for semantic analysis
- Interpreting natural language to associate text and speech with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Recognizing patterns in data and information to get insights and find meaningful associations to relevant knowledge
- Knowledge of the values and goals of the company and unit and of a wide range of issues
- Structured knowledge of time, people's positions, expertise and responsibilities
- Relevance evaluation to guide focus and tell important information and knowledge apart from less important in terms of serving values and goals
- Semantic analysis of various factors of the situation to make inference and evaluate their relevance
- Evaluating evidence to evaluate probability and confidence of facts
- Evaluating own confidence to recognize gaps in own knowledge and to know what kind of information is still needed
- Goal formulation to periodically determine how to continue with situation to reach desired values
- Synthesizing knowledge to come up with ideas solution alternatives, and decisions with certain parameters in mind that might solve the problem
- Inference to derive relevant logical conclusions about the object under analysis to get a better comprehension of the situation and to evaluate their relevance
- Categorizing to put data and information into reasonable information structure

- Producing natural language to communicate with relevant people in the situation by written text or speech
- Gesturing to express attitude and desire to get something done other party
- Operating computer programs to communicate, search for data and information, change systems and many other things
- Operating machines and devices to solve a problem related to a machine or that can be helped by using a machine
- Communication to externalize information
- Physical action to make gestures that facilitate getting the point across

Making changes in systems (3 tasks):

- Perception to take in textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting natural language to comprehend systems in order to make changes
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the system at hand and of the values and goals of the company and unit
- Programming to make systems function in a desired way
- Operating computer programs to make changes in the system
- Communication to give commands to the system

Operating machines (2 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form from machines
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the machine at hand and of values and goals of the company and unit
- Structured knowledge machine's types and properties
- Relevance evaluation to tell important information and knowledge apart from less important in terms of serving goals and values of the discussion
- Operating machines and devices to test machines or to get a task done using machines
- Communication to give commands to machines
- Physical action to use interfaces and move various parts of machines

Compiling documents (4 tasks):

- Perception to take in visual signals or textual and numerical information (alternatively can operate through receiving data apart from visual signals)
- Receiving data to take in textual and numerical information in a digital form
- Interpreting visual information of documents to produce information for semantic analysis and relevance evaluation
- Interpreting natural language to associate speech with relevant knowledge and to produce natural language
- Learning to improve the utilization of the knowledge capabilities in performing the task
- Knowledge of the issue at hand, of document formalities, and of the values and goals of the company and unit
- Semantic analysis of the topic and the users of the document to evaluate relevance of information and suitability of different layouts, structures and elements
- Relevance evaluation to guide focus and tell important information and knowledge apart from less important in terms of serving values and goals

- Goal formulation to periodically determine how to continue with the document compilation process to reach desired values
- Categorizing to put data and information into reasonable information structure
- Producing natural language to express knowledge in written text
- Operating computer programs to write information into documents, do document formatting, and access data and information
- Communication to externalize information

Overall, I analysed the required knowledge capabilities for the 25 task types. Table 18 presents the sum of times each capability occurs the task types in descending order under the three knowledge capability categories:

Table 18 Number of occurrences of knowledge capabilities in the 25 task types

Input capabilities	Processing capabilities	Output capabilities
Interpreting natural language: 18	Learning: 25	Communication: 21
Perception: 17	Knowledge: 20	Operating computer programs: 11
Receiving data: 13	Relevance evaluation (occurs always with values): 15	Producing natural language: 9
Interpreting visual information: 11	Categorizing: 15	Physical action: 6
	Inference: 14	Gesturing: 5
	Semantic analysis: 12	Producing simple language: 4
	Goal formulation: 9	Operating machines and devices: 3
	Evaluating own confidence: 9	Programming: 1
	Structured knowledge: 7	
	Synthesizing knowledge: 4	
	Evaluating evidence: 4	
	Recognizing patterns in data and information: 4	

From the table we can see that learning (25), communication (21), knowledge (20) and interpreting natural language (18) were the most commonly occurring knowledge capabilities. This was well expected as learning can be involved in every situation and knowledge work is largely based on processing of information, natural language and externalizing information through communication. Of the other knowledge capabilities, the most commonly occurring in the task types were perception (17), relevance evaluation (15, occurs always with values), categorizing (15), and operating computer programs (11). These results do not, however, give an accurate picture of their importance or how frequently they are utilized in everyday knowledge work, as some task types are performed more often than others.

6.3 Analysis of Watson's knowledge capabilities and their coverage of the task types' required capabilities

In this part of my analysis, I shall first analyse what knowledge capabilities Watson possesses according to the framework of knowledge agent's knowledge capabilities. After that, I shall compare Watson's knowledge capabilities against the required knowledge capabilities in the task types and count the coverage.

6.3.1 Watson's capabilities according to the framework of knowledge agent's knowledge capabilities

In Chapter five, Watson's knowledge capabilities were presented. They were adopted from IBM's publications on Watson. Table 19 presents the capabilities.

Table 19 Watson's capabilities

Gives simple answers to natural language questions	Analyses large volumes of structured, semi-structured and unstructured data
	Interprets and understands natural language questions
	Generates and evaluates hypotheses and quantifies confidence in answers
Supports iterative dialogue to refine results	Identifies gaps and uncertainties in knowledge
	Presents simple natural language questions to decrease uncertainty
Adapts and learns to improve results over time	Recognizes patterns
	Alters concepts and categories

For the purpose of conducting the analysis section of this study, these capabilities need to be converted to the framework of knowledge agent's knowledge capabilities. The capabilities of Watson according to the framework are as follows:

Input capabilities

- **Receiving data** to take in incoming digital information
- **Interpreting natural language** to associate text and speech with relevant knowledge and to produce natural language

Processing capabilities

Central capabilities

- **Structured knowledge** of concepts, categories, various domains, time, and place
- **Learning** to improve the utilization of the knowledge capabilities in performing the task

Left-hand side processing capabilities

- **Semantic analysis** of the source material to discern its elements and characteristics to help evaluating evidence and confidence
- **Evaluating evidence** to calculate the confidence level for answer candidates
- **Evaluating own confidence** to inform the user about the confidence level and/or determine whether to give an answer or discard it
- **Inference** to produce more evidence from logical conclusions to eliminate and understate unlikely answers and to emphasize probable ones

Right-hand side processing capabilities

- **Recognizing patterns in data and information** to make generalizations and statistical aggregation

Output capabilities

- **Producing simple language** to express answers in a formal structure
- **Communication** to give answers in simple language verbally or digitally

In Figure 19 the capabilities of Watson that cover the human knowledge worker capabilities are presented in the knowledge worker knowledge capabilities framework:

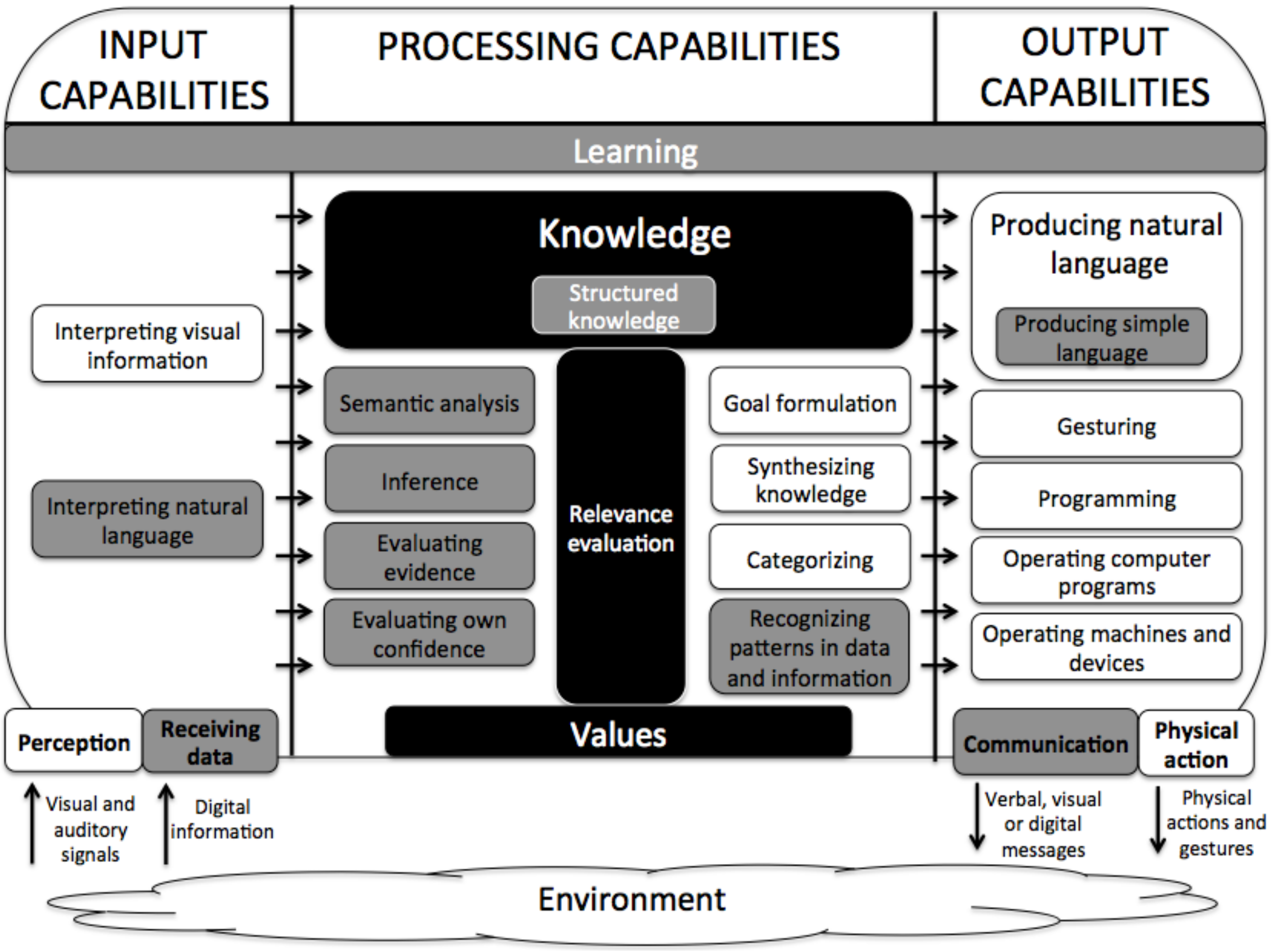

Figure 19 Capabilities that Watson covers in the knowledge worker framework

The squares with grey background are capabilities that are covered by Watson, whereas the squares with white background are ones that only humans possess and are beyond Watson's set of capabilities. Besides learning, which is in this framework considered as a fundamental capability that is present in every situation, the capabilities that can be considered covered by Watson include interpreting natural language, structured knowledge, semantic analysis, evaluating evidence, evaluating own confidence, inference, and producing simple language. Although Watson can be considered capable of some level of knowledge and not just structured knowledge, it is still nowhere near the complexity of human knowledge that includes a lifetime's experience and with that all the connotations that have been built into concepts, words, phrases, sentence structures, mental models etc. For this reason, Watson's capabilities do not cover knowledge in this framework. As to operating computer programs, Watson's capability is limited to accessing databases and other data and information resources like the Internet. It is not however capable of operating other sort of computer programs such as spread sheets or image editing software.

6.3.2 Analysis of the coverage of Watson's knowledge capabilities in knowledge work task types

In this part of the analysis, the number of those knowledge capabilities of Watson that overlap the required knowledge capabilities in each knowledge work task type is counted. The number is also compared with the total number of required knowledge capabilities in each knowledge work task type, from which proportions are calculated. In some task types, the knowledge capabilities of perception and receiving data can be utilized interchangeably. These include those task types where the incoming information is textual or numerical and can thus be received either in digital form or read visually from paper or a computer screen.

INTERNAL: Analytical tasks

Checking and approving / disapproving (7 / 12 ~ 58% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Semantic analysis, Evaluating own confidence, Inference, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Producing natural language, Operating computer programs

Investigating (9 / 14 ~ 64% of capabilities):

Covered: Receiving data, Recognizing patterns in data and information, Interpreting natural language, Learning, Semantic analysis, Evaluating evidence, Evaluating own confidence, Inference, Communication

Not covered: Knowledge, Categorizing, Goal formulation, Producing natural language, Operating computer programs

Gathering data and information (6 / 11~ 55% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Evaluating evidence, Evaluating own confidence, Communication

Not covered: Knowledge, Relevance evaluation, Categorizing, Goal formulation, Operating computer programs

Monitoring (5 / 9 ~ 56% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Structured knowledge, Communication

Not covered: Interpreting visual information, Knowledge, Relevance evaluation, Operating computer programs

Recognizing patterns and possibilities (6 / 11 ~ 55% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Recognizing patterns in data and information, Inference, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Relevance evaluation, Operating computer programs

Scheduling (4 / 9 ~ 44% of capabilities):

Covered: Learning, Semantic analysis, Inference, Communication

Not covered: Knowledge, Structured knowledge, Relevance evaluation, Categorizing, Operating computer programs

Testing programs (6 / 11 ~ 55% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Semantic analysis, Inference, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Relevance evaluation, Operating computer programs

Using analyzing tools to create information and insights (5 / 8 ~ 83% of capabilities):

Covered: Receiving data, Learning, Semantic analysis, Inference, Communication

Not covered: Perception, Knowledge, Operating computer programs

Visual analysis (3 / 7 ~ 43% of capabilities):

Covered: Learning, Semantic analysis, Inference

Not covered: Perception, Interpreting visual information, Knowledge, Categorizing

INTERNAL: Synthetical tasks

Evaluating and deciding (6 / 12 ~ 50% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Semantic analysis, Evaluating own confidence, Inference

Not covered: Perception, Interpreting visual information, Knowledge, Relevance evaluation, Goal formulation, Synthesizing knowledge

Generating ideas and alternative solutions (2 / 7 ~ 29% of capabilities):

Covered: Learning, Inference

Not covered: Knowledge, Relevance evaluation, Categorizing, Goal formulation, Synthesizing knowledge

Hypothesizing (4 / 7 ~ 57% of capabilities):

Covered: Learning, Recognizing patterns, Semantic analysis, Inference

Not covered: Knowledge, Categorizing, Synthesizing knowledge

EXTERNAL: Communicative tasks

Answering questions (9 / 9 ~ 100% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Semantic analysis, Evaluating evidence, Evaluating own confidence, Inference, Producing simple language, Communication

Not covered: none

Delegating (6 / 9 ~ 67% of capabilities)

Covered: Interpreting natural language, Learning, Structured knowledge, Semantic analysis, Inference, Communication

Not covered: Relevance evaluation, Categorizing, Producing natural language

Directing discussion (3 / 11 ~ 27% of capabilities):

Covered: Interpreting natural language, Learning, Communication

Not covered: Perception, Interpreting visual information, Relevance evaluation, Goal formulation, Categorizing, Producing natural language, Gesturing, Physical action

Discussing and deciding together (5 / 14 ~ 36% of capabilities):

Covered: Interpreting natural language, Learning, Evaluating own confidence, Inference, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Categorizing, Goal formulation, Categorizing, Producing natural language, Gesturing, Physical action

Information disseminating (5 / 6 ~ 83% of capabilities):

Covered: Interpreting natural language, Learning, Structured knowledge, Producing simple language, Communication

Not covered: Categorizing

Explaining knowledge (3 / 7 ~ 43% of capabilities):

Covered: Interpreting natural language, Learning, Evaluating own confidence

Not covered: Knowledge, Goal formulation, Categorizing, Producing natural language

Persuading and negotiating (3 / 9 ~ 33% of capabilities):

Covered: Interpreting natural language, Learning, Communication

Not covered: Perception, Knowledge, Relevance evaluation, Producing natural language, Gesturing, Physical action

Prompting people (4 / 7 ~ 57% of capabilities):

Covered: Learning, Structured knowledge, Producing simple language, Communication

Not covered: Relevance evaluation, Gesturing, Physical action

Requesting information (5 / 7 ~ 71% of capabilities):

Covered: Interpreting natural language, Learning, Evaluating own confidence, Producing simple language, Communication

Not covered: Knowledge, Relevance evaluation

EXTERNAL: Operative tasks

Handling sudden problems / fire fighting (10 / 22 ~ 45% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Recognizing patterns in data and information, Structured knowledge, Semantic analysis, Evaluating evidence, Evaluating own confidence, Inference, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Relevance evaluation, Goal formulation, Synthesizing knowledge, Categorizing, Producing natural language, Gesturing, Operating computer programs, Operating machines and devices, Physical action

Making changes in systems (4 / 7 ~ 57% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Communication

Not covered: Knowledge, Programming, Operating computer programs

Operating machines (4 / 9 ~ 44% of capabilities):

Covered: Receiving data, Learning, Structured knowledge, Communication

Not covered: Perception, Knowledge, Relevance evaluation, Operating machines and devices, Physical action

Compiling documents (5 / 13 ~ 38% of capabilities):

Covered: Receiving data, Interpreting natural language, Learning, Semantic analysis, Communication

Not covered: Perception, Interpreting visual information, Knowledge, Relevance evaluation, Goal formulation, Categorizing, Producing natural language, Operating computer programs

6.4 Overview of Watson's complementary and replacing potential

In the previous analysis, the capabilities of Watson were analysed and compared against the required capabilities for the 25 task types that were formed by examining the five knowledge work jobs. In this overview, I shall summarize the findings of analyzing Watson's that give a rough idea on the performance potential of Watson in knowledge work.

Of the capabilities that Watson does not cover, the ones with most occurrences in the task types were:

- Knowledge (20 occurrences)
- Perception (17 occurrences)
- Relevance evaluation (15 occurrences)
- Categorizing (15 occurrences)
- Operating computer programs (11 occurrences)
- Producing natural language (9 occurrences)

From this we can conclude that Watson's lack of knowledge capabilities resides largely in the domains of fundamental capabilities, right-hand side processing capabilities, and the more sophisticated output capabilities.

The task types that Watson's knowledge capabilities covered the most were

- answering questions (~100% of the required knowledge capabilities)
- using analyzing tools to create information and insights (~83% of the required knowledge capabilities)
- information disseminating (~83% of the required knowledge capabilities)
- requesting information (~71% of the required knowledge capabilities)
- delegating (~67% of the required knowledge capabilities)

The required knowledge capabilities in the task type of answering questions were found to be the most covered by Watson's knowledge capabilities. This was well expected as Watson was originally designed to do just that. Watson's knowledge capabilities also covered well the task types of information disseminating, investigating and requesting information as these entail mainly the left-hand side knowledge capabilities of the processing capabilities that Watson possesses.

The task types that were the least covered by Watson's capabilities were

- directing discussion (~27% of the required knowledge capabilities)
- generating ideas and alternative solutions (~29% of the required knowledge capabilities)
- persuading and negotiating (~33% of the required knowledge capabilities)
- discussing and deciding together (~36% of the required knowledge capabilities)
- compiling documents (~38% of the required knowledge capabilities)

The reason for Watson's capabilities' low coverage in these task types can be found in that they frequently involve fundamental capabilities (knowledge, relevance evaluation), right-hand side processing capabilities, and the more sophisticated output capabilities (producing natural language and using computer programs) that are not part of Watson's set of knowledge capabilities.

As for the knowledge work task categories, the average knowledge capability coverage for the categories were found to be as follows:

- INTERNAL: analytical tasks: ~44%
- INTERNAL: synthetical tasks: ~40%
- EXTERNAL: communicative tasks: ~49%
- EXTERNAL: operative tasks: ~30%

All in all, from this ratio it may be said that Watson's performance potential seems to be strongest in the knowledge work task types that entail the left-hand side knowledge capabilities of the processing capabilities in the knowledge agent's knowledge capabilities framework. These capabilities can be seen as highly related to analytical knowledge processes. In the knowledge task categories, Watson's knowledge capabilities were found to be having the greatest coverage in communicative and analytical tasks, which can be explained by Watson's capabilities of interpreting natural language, its left-hand side processing capabilities and structured knowledge, and its capability to produce simple language.

7 CONCLUSIONS

One of the purposes of this research project was to deepen the understanding of knowledge work through identifying roles and task types that contemporary knowledge workers perform. Another purpose was to better understand which knowledge capabilities still make present-day human knowledge workers so unique that organisations continue to depend on us instead of relying on computer systems. In other words, what are the knowledge work roles and task types of knowledge workers today that could be performed by machines, and what knowledge capabilities can still be found exclusively in the human domain? To grasp a better understanding to these questions, I used a state-of-the-art, artificially intelligent computer system, Watson, as a case to examine to what extent its knowledge capabilities might overlap those of human knowledge workers and made speculations on what types of tasks it would be able to complement or even replace knowledge workers based on how largely its knowledge capabilities cover the required knowledge capabilities in contemporary knowledge work task types.

In this Chapter, I first discuss the study's findings in the context of knowledge work research. After that, I reflect the managerial implication of knowledge work research, Watson and artificially intelligent computer systems. Finally, I conclude this research project with a discussion on the limitations of the research, give recommendations for future research, and give my concluding thoughts on the subject in a general sense.

7.1 Theoretical contribution

7.1.1 Knowledge work typology and the knowledge agent's knowledge capability framework

Identifying knowledge work task types, task categories and knowledge capabilities employed to perform them gives us relevant means for a systematic study of knowledge work. As humans still largely perform knowledge work, it is essential to understand the human mind that is utilized in knowledge work. For this, the fields of cognitive psychology and neuroscience in particular are playing an important part in creating accurate descriptions of how the human mind performs various knowledge work tasks. This enables finding ways to develop new means, new technologies and new applications to meet the needs of the human mind in carrying out knowledge work tasks.

Confluences in the typology between this study and the studies presented in the literature Chapter can be found. Mintzberg's (2009) competencies, Reinhardt's et al. (2011) knowledge actions, and the knowledge work task types in the typology of this study can be considered counterparts to each other. Exact counterpart cannot be found for each task types in the competencies and knowledge actions, rather many of them can be regarded as constituents or special cases of the task types. Table 20 presents the knowledge work task types and their closest counterparts in Mintzberg's (2009) list of competencies and Reinhardt's et al. (2011) list of knowledge actions. Some knowledge work task types are associated with more than one competency or knowledge action.

Table 20 Comparison of task types to Mintzberg's competencies and Reinhardt's et al. knowledge actions

Typology of knowledge work task types	Mintzberg's (2009) competencies	Reinhardt's et al. (2011) knowledge actions
Internal: Analytical tasks		
Checking and approving	Authorizing	-
Investigating	Managing information, Information gathering	Expert search, Information search, Service search
Gathering data and information	Managing information, Information gathering	Acquisition, Information organisation, Information search
Monitoring	Data processing	Monitoring
Recognizing patterns and possibilities	Reflecting, Strategic thinking	Analyze
Scheduling	Managing time, Chunking, Prioritizing, Agenda setting, Juggling, Timing	Information organisation
Testing programs	-	Analyze, Feedback
Using analyzing tools to create information and insights	Data processing, Modeling, Measuring	Analyze
Visual analysis	Data processing	Analyze, Feedback
Internal: Synthetical tasks		
Evaluating and deciding	Reflecting, Strategic thinking, Goal setting	Feedback
Generating ideas and alternative solutions	Planning, Visioning	-
Hypothesizing	Reflecting, Strategic thinking	Analyze
External: Communicative tasks		
Answering questions	Information disseminating	Dissemination
Delegating	Delegating	-
Directing discussion	Resolving conflicts/mediating, Running meetings, Interviewing	Networking
Discussing and deciding together	Collaborating, Negotiating/dealing, Project managing	Networking, Co-authoring
Disseminating information	Information disseminating	Dissemination
Explaining knowledge	Speaking/presenting/briefing, Writing	Dissemination
Persuading and negotiating	Team building, Resolving conflicts/mediating, Building culture, Performance appraising, Networking, Politicking	Networking
Prompting people	-	-
Requesting information	Interviewing	Expert search, Service search
External: Operative tasks		
Handling sudden problems / firefighting	Firefighting	-
Making changes in systems	-	-
Operating machines	-	-
Compiling documents	Writing	Authoring, Co-authoring, Information organisation

Table 20 does not take into account the roles that can be found both in Mintzberg's (2009) and Reinhardt's et al. (2011) studies, as this study did not formulate a typology of the roles of the five knowledge workers. Confluences can be found between Mintzberg's (2009) roles of managing and the knowledge work categories of this study. The most apparent correspondence can be found between the division to external and internal in Mintzberg's (2009) model and the model of this study, although in Mintzberg's (2009) model, the division spans across all his three planes. As for Mintzberg's (2009) planes in his model, the best correspondent can be found in the knowledge work task categories. At that level, the most apparent confluences are between Mintzberg's (2009) action plane and operative tasks category, and Mintzberg's people plane and communicative tasks category. Mintzberg's (2009) information plane can be considered entailing both the analytical and synthetical tasks categories. The concepts knowledge work task type and Reinhardt's et al. (2011) concept of knowledge action can be considered to be at the same level of processing information, although the knowledge action seem to take a slightly higher level, even though its name suggests otherwise.

As for the knowledge agent's knowledge capabilities framework, the concept of knowledge capability does not find a clear conceptual correspondent in any of the studies presented in this research. Neither can the concept be considered to reside at a cognitive level, because cognitive psychology studies phenomena at a very elemental level of information processing, although the names of some the knowledge capabilities can be found in the field of cognitive psychology such as perception or categorization. Knowledge capabilities can be considered as entities possessed by knowledge agents, which enables them to perform knowledge processes. A conceptual solution for knowledge processes is to place them in between knowledge work task types (or knowledge actions) and cognitive processes. Knowledge capabilities, then, reside between knowledge agents and cognitive capabilities.

Having said this, an extended hierarchy for levels of information processing can be proposed. In Table 21, a hierarchy of different levels of information processing is presented. It extends underneath the domain of a knowledge agent in this hierarchy where the capabilities for information processing possessed by knowledge agents can be found, and over this domain where reside the different levels of organisation encompassing the collaboration of more than one knowledge agent.

Table 21 Hierarchy of information processing

Information processing entity	Level of information processing
Value chain	Value chain processes
Organization	Organizational processes
Organizational unit	Organizational unit processes
Team	Team processes
Knowledge agent	Knowledge work roles, knowledge work task types (or knowledge actions)
Knowledge capability	Knowledge processes
Cognitive capability	Cognitive processes

Table 21 proposes that the nature of goal oriented information processing is about making different levels of information processing entities to collaborate together in order to achieve various goals. A knowledge agents, which can mean both a human knowledge worker or a computer, orchestrates its knowledge capabilities to perform knowledge work tasks in the same way as an organisation mobilizes organisational units to perform its organisational processes. Here again, the concept of role can be considered as a bundle of tasks or processes, and can be applied at different levels of the proposed hierarchy. One may say that a knowledge agent has many roles that it performs by executing knowledge work tasks in concert in the same way as a team has many roles, and performs them by juggling different team processes or tasks in an appropriate fashion.

7.2 Managerial implications

7.2.1 Managerial implications of knowledge work research

In order to organise knowledge work more effectively and to develop new knowledge work enhancing business applications, organisations need to understand the nature of knowledge work. Creation of comprehensive typologies for knowledge work roles and tasks and construction of frameworks for knowledge and cognitive capabilities are initial steps in the process of rationalizing knowledge work. Rationalization also paves way for automatizing work processes.

From the perspective of the production side of the market, research and rationalization of knowledge work through typologies and frameworks will enable mapping how much different knowledge work task types and knowledge work roles are present in today's economy. Economists would be able to measure the proportion of various knowledge work roles or task types in different industries, economic regions and the whole world economy. Companies would then use this new type of data about the prevalence of different knowledge work roles and tasks in various industries. They could start developing knowledge work tools, artificially intelligent computer systems and software to meet the demands in different industries and organisations. A great new market could be opening up for knowledge work tools and automating knowledge work that is currently performed by humans.

Knowledge work research and rationalization can also help develop better methods and protocols for performing knowledge work in the same way that was done in manual factory work with the help of Scientific Management. For example, educational institutions could establish new fields of study where finding ways of conducting knowledge work more efficiently are studied, and future knowledge workers would be educated and trained based on the knowledge acquired through research. It is also important for knowledge workers themselves to understand what they are doing in order to enhance their efficiency and effectiveness.

Knowledge capabilities in the knowledge work task types

The analysis of this study's sample of five knowledge work jobs revealed that some knowledge capabilities were more commonly utilized in the knowledge work types than others. Learning was found to be present in all of the knowledge work task types, as every situation can produce learning on how to enhance the utilization and collaboration of different knowledge capabilities to achieve goals. Learning can, therefore, be considered among the most important knowledge capabilities as it develops existing knowledge task capabilities but also enables creating new knowledge and skills. Although in this study, Watson was considered to possess the knowledge capability of learning, its learning does not the reach the depth and scope of human learning. Unlike humans, Watson cannot learn new knowledge capabilities or knowledge task capabilities (skills), although it can develop its existing knowledge capabilities and skills and acquire new structured knowledge or even real knowledge of a certain level. Humans, on the other hand, can learn altogether new knowledge capabilities and skills by integrating one's existing capabilities. For example, a human can learn to speak, that is, to produce natural language, but Watson cannot learn this on its own.

Unsurprisingly, perception (17) and receiving data (13 occurrences) along with communication (21) were found to be commonly occurring knowledge capabilities. This is due to the fact that work involves being engaged with the environment, which these knowledge capabilities enable.

Interpreting natural language with its 18 occurrences was similarly expected to be a prevalent knowledge capability, since knowledge work by its very nature is processing symbols. Natural language is the main tool that knowledge workers convey meaning. Producing natural language (9 occurrences) was also found to be commonly utilized. Up to this point, no artificially intelligent computer system has been attributed to possess this knowledge capability. The computerization of producing natural language would most likely have a huge impact on knowledge work, as it would allow computers to explain knowledge, produce documents and along with interpreting natural language have conversations with people, too. Yet, producing natural language involves many complex knowledge process capabilities, therefore making its computerization hugely challenging.

The knowledge capabilities of knowledge (20 occurrences) and relevance evaluation (15 occurrences) were also found to be common in performing knowledge work tasks. As the term knowledge work suggests, knowledge is associated with it, as knowledge agents need to know about the objects, the environment and the laws governing the environment they act in. Human level of knowledge involves a vast array of associations, built by endless set of connotations and life experience. For this reason, computerization of knowledge at a human level can prove out to be hugely challenging as well, although knowledge work in itself might not require such a deep level of associations, since work by its nature is merely concerned about production of goods and services. As for relevance evaluation, it gives a knowledge agent capability of reflecting situational information and knowledge to its values. This knowledge capability, which can be largely associated with "common sense", may be among the hardest knowledge capabilities to understand and model. Its computerization would pave way for automatizing a large array of tasks, including managerial ones. Computerizing relevance evaluation would also probably require modelling and programming of values.

In light of the analysis, it seems that generally the knowledge capabilities in the left-hand side of processing capabilities are most prone to computerization. Knowledge capabilities that are unlikely going to face computerization in the near future, are the right-hand side synthetical and central processing capabilities, as creativity and executive functions could be very challenging to model and program. These include relevance evaluation, goal formulation and synthesizing knowledge. As was noted by Brynjolfsson and McAfee (2011), structured, middle-skill knowledge work jobs that involve routine knowledge work tasks are getting automated first, but jobs that are considered *non-routine*, entailing *big picture thinking*, and executive level jobs, might avoid waves of automation longer.

7.2.2 Managerial implications of Watson

In the light of this study, it appears that Watson could have significant performance potential in certain knowledge work tasks types. Watson can understand natural language, process information analytically, and communicate with the environment with simple language, like giving short answers or asking simple, clarifying questions. In short, it is a machine whose knowledge capabilities allow its users to get accurate answers fast from vast information sources, enabling it to be used as a tool to conduct investigation, checking facts, diagnosing problems and finding solutions to them that already exist.

In this study, many of the knowledge work tasks were of such nature that the capability of Watson to extract answers and find evidence for them complements the knowledge worker. Checking facts may often take the knowledge worker a lot of time, but Watson renders the task of checking facts and answers shorter, therefore saving time for the cognitively more challenging tasks. It can also help to increase the efficiency of performing other knowledge work tasks, as Watson can quickly find well-established facts and answers with evidence and confidence analysis that then provides better-established perspectives for knowledge workers in decision-making. Yet, Watson cannot synthetize knowledge or work on its own to accomplish complex tasks that involve setting goals and planning like, for example, designing new business processes or evaluating business plans as a whole. One can say that these capabilities can be considered to involve 'big picture' thinking and humane cognitive processes that probably need great endeavours in scientific and technological development in order to be computerized.

Integration of cognitive capabilities is needed in order to make artificially intelligent computer systems that can perform various knowledge work task types. With Watson, only the task type of answering questions was fully achieved. Combining Watson's knowledge capabilities in a novel way or developing new knowledge capabilities, namely those of the right-hand side processing capabilities and output capabilities, could allow it to perform other perhaps more challenging tasks that are involved in creative and executive knowledge work tasks.

7.2.3 Managerial implications of artificially intelligent computer systems

Many people have heard perhaps from university management lectures that the most valuable asset of an organisation are its people. Often it can be viewed as just that—human beings possess astonishing motor, cognitive, and cooperative capabilities and adjustability to changing circumstances. On the other hand, payrolls represent the greatest share of costs to many organisations. From the perspective of a global multinational company, personnel costs can add up to a lion's share of firms' expenses. Especially in knowledge intensive organisations that rely highly on knowledge workers, such as experts and other highly educated professionals, staff expenses are by far among the greatest factors generating costs. Moreover, knowledge workers own the human capital often giving them great negotiation power over organisations, which adds to organisations' dependence on them. For this reason, automatizing knowledge work and thus lowering personnel expenses, specifically in knowledge intensive industries, may well become the single most important competitiveness-driving factor for firms as the 21st century progresses and technology develops to enable it.

Much talk has also been going on in the media and among researchers about the polarizing nature of the labour market where there is an increasing demand for work force in both, the low and high ends, of the job skill spectrum leaving the middle-skilled part dwarfed (see Brynjolfsson & McAfee, 2011). In many industries, such as the ICT, the most fiercely fought over work force are the high skilled, educated top professionals. As the proportion of these outstanding, talented and skilful professionals is hardly going to grow dramatically in the total workforce, it seems that there is more and more demand for finding ways to increase the productivity and performance of these individuals so as to extend their skills in which way to compensate their low number in the labour force. This could be achieved through outsourcing some of their less challenging knowledge work tasks to less-skilled knowledge workers or artificially intelligent computer systems, which means computerization. Wasted time and effort of extraordinarily talented and skilful people is waste in extraordinary magnitude.

Because certain high-level knowledge work roles and tasks can currently be performed only by a small number of knowledge workers, introducing artificially intelligent computer systems, the highly competent, educated, and creative knowledge workers and managers can enhance their own efficiency and effectiveness through outsourcing some of their more mundane tasks to artificially intelligent computer systems. Furthermore, as they are more or less today dependent on the work of the knowledge workers whose competence and education and creativity are not as high as theirs, these processes could be conducted and carried out with more efficiency in order to serve the knowledge work of these high-performing individuals.

This study proposes that there could be a great increase in the productivity of these high-performing, creative knowledge workers, as the new artificially intelligent computer systems could start performing analytical processes that often slow down their own work, because they have to do these tasks themselves or they have to wait and rely on the performance of the people doing routine knowledge work that are there to refine and produce information for them.

As artificially intelligent computer systems continue to develop and start having more and more knowledge capabilities that have so far been possessed only by humans, it will open up the possibility to model and build systems that can take the role of humans in performing knowledge work processes, tasks, and roles. In Figure 20 the process of work analysis, capability modelling and programming, and integrating is depicted.

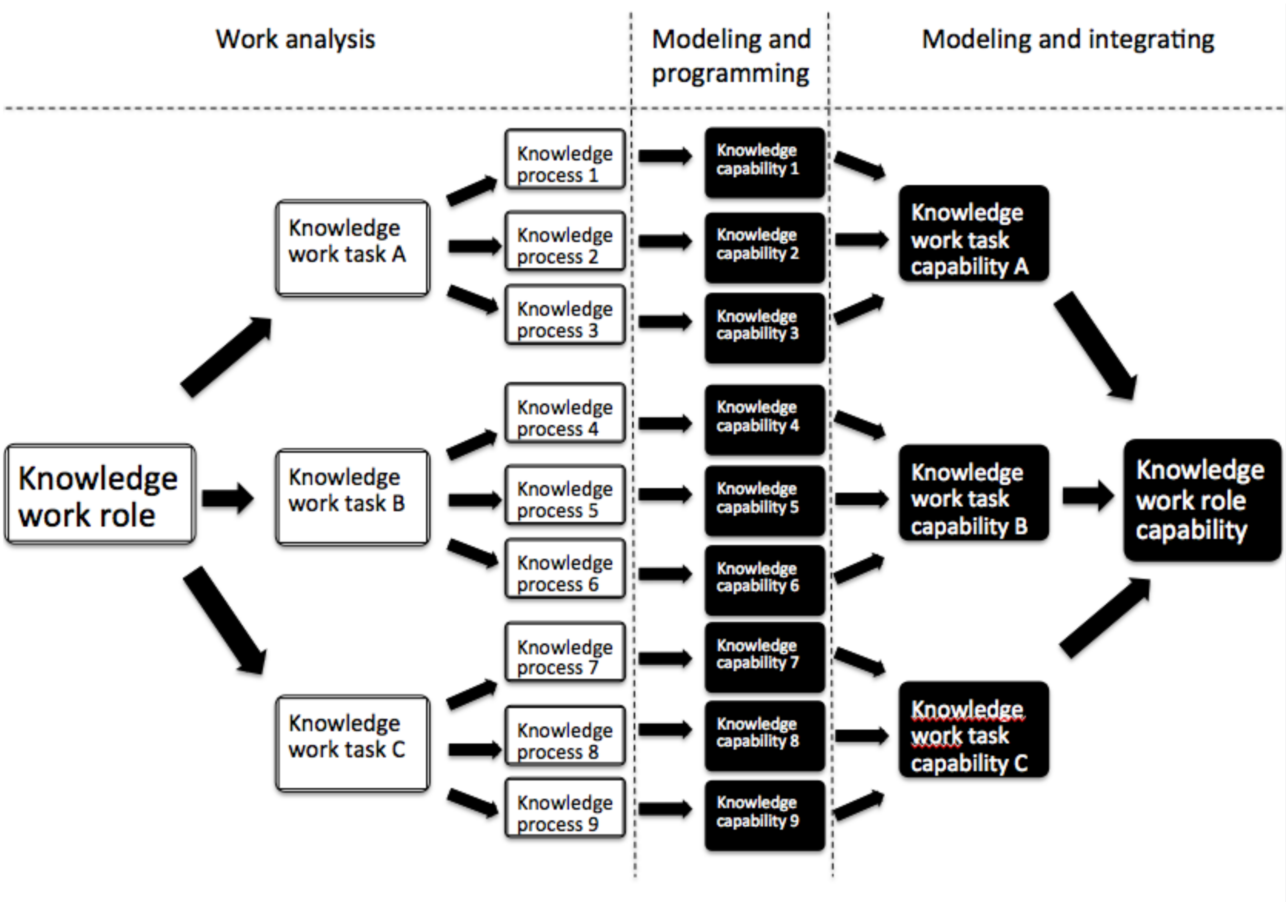

Figure 20 The process of breaking down knowledge work roles and computerizing them

In the far left of Figure 20, there is a knowledge work role performed by a human knowledge worker. The knowledge work role is broken down into knowledge work tasks, which are further disintegrated into knowledge processes, which could be fractured further into cognitive processes, although this is not presented in Figure 20. The human knowledge processes are then modelled and programmed into computer version of knowledge capabilities, which in turn are integrated into knowledge task capabilities, such as answering customers' questions via phone, or making medical diagnoses based on given patient information. Finally, the knowledge task capabilities are further integrated into more comprehensive knowledge work role capabilities, such as organising events, managing projects, or conducting investigations on various issues.

How should knowledge work roles and tasks then be modelled? One approach could be what Reinhardt et al. (2011) did in their study. They recorded the actions and operations of knowledge workers using computer activity monitors, sensors, and video cameras and asked the knowledge workers to explain what they were trying to get done and by what means. The data was then analysed and models were formulated. Knowledge-intensive companies could use the same approach of gathering data on the actions of their employees and then building models of how the knowledge work roles and tasks are performed. These models could then be used to introduce better protocols and best practices to perform the various roles and tasks, weeding out inefficient ways of conducting tasks at the individual level, and also for developing artificially intelligent computer systems that can perform the roles and tasks. Of course, recording the actions and communication of employees could raise some ethical questions and employees should be clearly informed in case the employer practices this kind of monitoring. However, the improvements in productivity could prove to be enormous, since knowledge work productivity can vary greatly from person to person.

Disruption in knowledge work

According to Christensen's (1997, 2003) theory of disruptive innovations, disruptive innovation is an innovation that facilitates generating, and in due course goes on to disrupt an extant market and value network, making an earlier technology obsolete. Christensen (1997, 2003) differentiates between "low-end disruption", which focuses on customers who have no need for the full performance of a product that are valued by the customers at the high end of the market and "new-market disruption" which focuses on customers who have needs that were not formerly served by extant incumbents. The disruptive technology may, at this point, enter the market providing a product or service which has poorer performance than the incumbent but which surpasses the needs of certain customers, thus gaining a foothold in the market. Once the disruptor has secured itself in the market, it seeks to improve its profit margins. In order to attain higher profit margins, the disruptor needs to start targeting the customers who are prepared to pay for higher quality. At this point, the disruptor needs to innovate in order to improve the quality in its product. The incumbent is going to move up-market and target its more lucrative customers, as it will not find it desirable to hold on to its share in a less profitable customer segment. In the course of multiple such encounters, the incumbent is cornered into serving smaller markets than initially. Eventually, the disruptive technology meets the needs of the most profitable customers and forces the incumbent out of the market altogether. (Christensen 1997, 2003). In Figure 21, the process of low-end disruption is depicted.

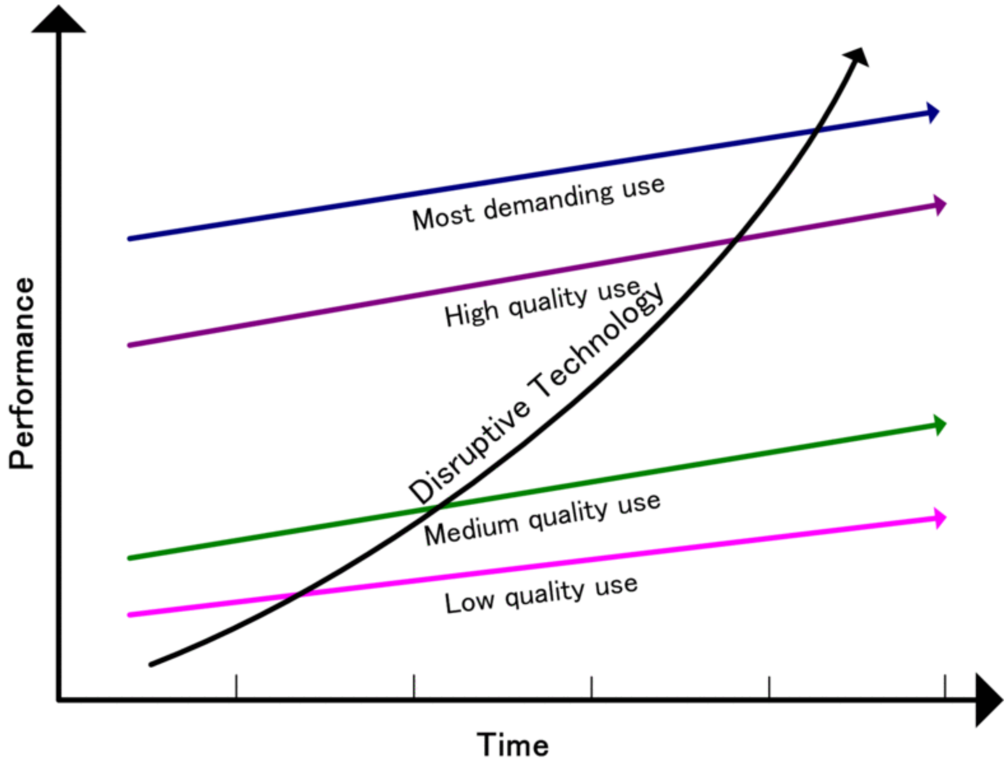

Figure 21 The process of low-end disruption over time (Christensen 1997, 2003)

Christensen's (1997, 2003) disruptive innovation theory can also be applied to computerization of knowledge work tasks. In case of artificially intelligent computer systems, computerized knowledge capabilities might not initially reach the performance level of humans in conducting knowledge work tasks in various professions. However, they could fulfil the needs of the low-end customers, by that means securing a foothold in the market. Once the knowledge work disruptor has established itself in the market of a given profession, it seeks to improve its profit margin by improving the performance level through innovation of new, more developed knowledge capabilities. During this process, the high-performing professionals are driven to ever shrinking markets, as the artificially intelligent computer system is gaining more and more share of the profession market, eventually displacing even the top professionals. A profession that has already started to witness this process is the legal profession. In March 2011, the New York Times published an article about computer software called e-Discovery, which helps analyzing millions of legal documents at a fraction of the cost and time that lawyers require. Having said this, a rather solid argument can be made that the process of disrupting knowledge work has already started in some knowledge work professions.

The development of artificially intelligent computer systems and their entrance to market could bring about a megatrend that could be called the diffusion of expertise and intelligence. Up to this point, intelligence and high-level expertise have been scarce resources. With humans, learning a skill or profession can take up to ten years. Every human being has to start learning things from the very beginning. With computers, it is different. When a computer learns something, it becomes integrated to its programming, a part of its software. Computer software has the attribute of being able to be copied to another computer. What one computer learns at any given time can, thus, be copied to millions of computers in a matter of hours or minutes via the World Wide Web. For example, if a computerized medical diagnosis system learns about some disease, such as lung cancer, under the period of five years, its "experience" can be copied to millions of computers performing the same task across the globe. The same logic goes for computers performing legal tasks, marketing tasks, economic optimization etc. This could mean that the supply of intelligence and expertize could surge in the future. Where ever intelligence or expertize is needed, the best knowledge will be available for anyone at anytime.

7.3 Limitations and future research

A notable limitation in this research project was the small empirical sample. A larger sample size, where more knowledge workers would have been interviewed from a wider range of industries might have revealed more roles and tasks and with them possibly a different set of knowledge work task categories, knowledge work task types, and even knowledge capabilities. Moreover, interview as a method relies on the memories, mental models, and descriptions by the knowledge workers of their work. Interviews combined with an ethnographic study would have undoubtedly elicited a more precise and objective picture of the content of their work. A larger sample size with more variety in terms of knowledge work jobs and industries fused with ethnographic method could therefore be highly recommended in order to produce more precise models about knowledge work roles, task categories, tasks types, and knowledge capabilities.

Another limitation of the study is that the analysis investigated merely the number of knowledge work tasks types that each knowledge capability was involved in. This does not reveal how widely the knowledge capabilities were utilized in performing the different knowledge work tasks. Neither did the research setting give any idea on the amount of time that the knowledge work tasks took when performing knowledge work roles or how frequently the tasks were performed. Consequently, the results of the analysis give only a rough idea of the prevalence of each knowledge capability in the knowledge work task types under investigation. In order to gain a more precise picture of the prevalence of the various knowledge capabilities, research should be made to measure the time in the job that a knowledge worker uses for any task and the frequency of how often he or she performs the task. Moreover, a more detailed investigation should be conducted on how critical a part any knowledge capability has in performing a given task type. This could require the use of brain scanners to see what brain regions are activated in doing various knowledge work tasks.

In analyzing what the required knowledge capabilities for the knowledge work task types were, I went through all the tasks of the five knowledge workers a number of times and reflected what the knowledge capabilities are that the tasks require relying on the extensive readings on knowledge work and cognition. It is fair to say that this approach was somewhat speculative, since I had to form a mental model of my own on how the tasks were performed and hypothesize what knowledge capabilities were utilized during the tasks. Even though this loses value in the objectivity of the study, this approach, nevertheless, may have produced some novel concepts and ideas about the nature and content of knowledge work.

Future research should focus on identifying more knowledge capabilities and knowledge work task types, and study the relationships between different knowledge capabilities and how they work in concert to perform knowledge work tasks. Also more research should be directed on studying the underlying cognitive capabilities that form the structure for the knowledge capabilities. Studies in the field of neuroscience and cognitive neuroscience could unravel some of those processes. Furthermore, understanding the role of neurotransmitters in the workings of knowledge capabilities and knowledge work performance could open new perspectives.

7.4 Concluding thoughts

As the proportion of farmers and manufacturing workers continues to represent an ever-shrinking share of the total workforce in developed countries, the increase of the productivity of knowledge workers and service workers is becoming ever more paramount (Drucker 1995, see Davis & Naumann 1999):

> *"The chief economic priority for developed countries, therefore, must be to raise the productivity of knowledge and service work. The country that does this first will dominate the twenty-first century economically." —Peter F. Drucker (1995)*

As early as in the 18th century, Adam Smith named the three main ingredients of an economy: land, labour, and capital. Knowledge work in itself is a type of labour. Artificially intelligent computer systems, like Watson, belong to a class of technology that enables complementing or altogether replacing tasks in knowledge work. It is also a state-of-the-art computer system whose capability of answering questions involves knowledge processes that overlap those of humans. As more artificially intelligent computer systems with knowledge capabilities like Watson's start entering the market and spreading throughout economies, it could at some point lead to the decrease in the demand for knowledge workers' labour, thus increasing the role of land and capital at the cost of labour. This will eventually pave the way for increasing negotiation power of employers as organisational processes become less and less dependent on human cognitive processes. However, this does necessarily concern the most creative, intelligent and skilful professionals who do non-routine knowledge work that requires hard-to-model knowledge capabilities. Furthermore, the negotiation power of these talented and skilful professionals can be expected to increase as the democratization of relevant information renders them less dependent on large, hierarchical organisations as stocks and providers of relevant information, creating new opportunities for organising work in dynamic networks (see Hagel, Brown & Davison 2010; Gray 2012).

As shareholders and top management in companies begin to realize the degree of knowledge work productivity increase that can be attained by complementing core knowledge workers with artificially intelligent computer systems and the amount of savings that can be achieved through automating knowledge work tasks and roles, the demand for such technology can be expected to increase substantially. Consequently, companies may be expected to start investing more on artificially intelligent computer systems to enhance business processes.

The development of artificially intelligent computer systems could also increase the productivity in research and development of these technologies, which in turn will lead to even faster development of understanding knowledge capabilities and development of relevant technologies, resulting in a virtuous circle of accelerating technological progress. The commercialization of artificially intelligent computer systems is likely to gain momentum and replacing knowledge workers with them in knowledge work could become a requirement for competitiveness in a number of industries. Of course, this could lead to a massive increase in unemployment, which would result in numerous societal problems. Even the very well known economist Keynes (1930) recognized the threat of technological unemployment:

> *"We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come—namely, technological unemployment. This means unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour." —John Maynard Keynes (1930)*

Perhaps, we are on our way to a world where the work, time and skill of a massive human work force is no longer an essential factor in the production of goods and services. Although artificially intelligent computer systems and robots may take over more and more tasks, there still needs to be people who hold the button and have the final say. In this scenario, we will arrive at a society where the role of humans in organisations has shrunk to the top-management positions, which encompasses only holding and wielding of power and responsibility, as the economy automation progresses. The demand of consumers and the values, power and responsibility of the people in charge of organisations will direct the automated production system.

One can envision some of the concrete consequences of this development—more and more office space in cities will be transformed into apartment buildings resulting in decreasing real estate prices as knowledge work processes gradually move from being performed inside the walls of these buildings into computer halls around the world that are interconnected to each other via the world wide web. Noisy traffic jams made of endless number of commuters could disappear and skyscrapers built for the purpose of providing space for office work that have characterized the horizons of the great metropolises for the last century will, perhaps, be occupied by completely different activities than those performed by people wearing whitecollar shirts sitting at their desks. Instead of spending tens of hours in the working place, people can use their new free time socializing with their family and friends, enjoying nature, starting new hobbies, making art and craftwork, reading literature, learning about history, science and philosophy, or start searching for deeper meaning in life.

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Interviews

Five anonymous knowledge workers in five different companies. Length: 60 minutes each.

Peltola, Ville, IBM, Innovation Manager. Length: 60 minutes.

APPENDIX

Appendix 1: Structure for the thematic interviews of the knowledge workers

Organisation and unit

- In what organisation and unit are you working in?

- What is the function of the unit you work in?

- What are the measures of your unit's performance?

- What unit processes are you involved in?

Nature and content of job

- What is your position?

- Describe how your typical workday goes by. Where does your time go?

- Who are you serving in your job and how?

- Who are serving you in your job and how?

- What kind of information you need in your job and where do you get it?

- What tools do you use in your job?

- What can be considered as the measures of performance in your job?

- What is frustrating in your job?

Potential benefit of Watson

- If you had had an assistant who would have answers for almost any question concerning your job, would this have been beneficial to you in your job? In what way?

Appendix 2: Structure for the thematic interview of IBM Finland's innovation manager, Ville Peltola, about Watson and DeepQA

Technology

- What kind of technology is Watson?
- To what other technologies can Watson and its DeepQA software be compared with?
- What limitations does Watson have thus far?
- How can the technology of Watson be expected to develop in the near future?

Organisation

- What is interesting in Watson from the perspective of an organisation?
- In what kind of processes can Watson be utilized in organisations and various professions?

Industries

- In which industries can Watson be expected to arouse the greatest interest and demand?
- To which industries and professions can Watson be expected to pose a threat?
- Has Watson given rise to a new industry?

Appendix 3: Descriptions of the tasks

Amadeus, user operations associate at Trendster Inc.

Amadeus's role 1: Developer of the automated user self-service system

Recognizing patterns in user data: In order to enhance the self-service system, Amadeus needs to identify relevant user behaviour.

Using statistics to verify hypotheses: As Amadeus spots a pattern in user behaviour that is relevant to the development of the system, he sometimes needs to use statistical methods to verify hypotheses.

Making changes in the system: When a behavioural hypothesis turns out to be valid and a useful modification is recognized, the system needs to be technically altered.

Testing the system: When the system is modified it needs to be tested. Amadeus does this by using the features of the system and observing, whether it works as planned and whether it feels right.

Amadeus's role 2: Localization person

Checking language translations: Checking language translation is basically reviewing language, spotting mistakes or poor choice of expressions in text and then correcting them.

Generating solution alternatives for back-up systems: In this task, Amadeus synthesizes knowledge into new ideas and develops them into solution alternatives with certain parameters in mind and identifies, analyses and evaluates problems, which the solutions might have.

Amadeus's role 3: Member of Site operations team

Hypothesizing causes of problems: Here Amadeus uses his experience and other knowledge in his mind about the various technical problem cases that have occurred with customers and analyses them in order to link them to known problems or synthesize new potential causes for problems. It also involves evaluating the probability of these hypotheses in his mind.

Answering technical questions: In this task, Amadeus uses his memory or other information resources to find answer candidates and provides the most probable one to the sales teams' representatives.

<u>**Amadeus's role 4: Direct user support person for Finnish users and companies**</u>

Verifying document authenticity: In this task, Amadeus needs to tell a real official document from a fake one.

Answering technical questions: Amadeus receives e-mails and phone calls, where customers ask him solutions to technical problems, and Amadeus provides them with answers.

<u>**Amadeus's role 5: Contact person**</u>

Answering questions: In this task, Amadeus answers to questions from customer firms and by phone or e-mail.

Asking questions for another party: Sometimes Amadeus lacks the knowledge to answer the questions himself. As a contact person, it is his task to ask an appropriate person for more accurate answers.

Explaining processes: Sometimes just an answer or detail is not enough and Amadeus needs to explain the knowledge he has on how a process is done to customer firms.

Delegating customer problems: In this task, Amadeus interprets the customers' problems, analyses to whom they are relevant and sends the problem to the right expert with additional information.

<u>**Amadeus's role 6: Job applicant evaluator**</u>

Visual analysis of job applicants: In this task, Amadeus analyses the outlook, gestures and habitus of job applicants.

Asking job applicants questions: In this task, Amadeus asks job applicants relevant questions.

Directing discussion in job interviews: In this task, Amadeus directs the interview and discussion with job applicants with his words and gestures.

Evaluating and deciding over job applicants: In this task, Amadeus participates in evaluating the qualities and suitability of various job applicants for different positions and takes part in deciding over whom to choose.

Arnold, project manager at NEOT

Arnold's role 1: Planner and organiser of tender preparation

Gathering relevant information from databases: Here Arnold enters the company's various databases and analyses the possible relevance of data and looks for data that he knows is relevant. He then gathers and organises the data into one place for later use in devising tender stipulations.

Devising stipulations for tender: To conduct this task, Arnold needs to understand the interests and restrictions of his company and the transportation firms. Devising stipulations has also to do with generating solution alternatives that work together as a whole and take many things into consideration at once.

Creating a formal tendering document: In this task, Arnold compiles tender stipulations into a formal document.

Sending tendering document to firms: When the document is ready and approved, Arnold needs to send it to the right recipients.

Gathering and organising bids: In this task, Arnold gathers the bids received from transportation firms and organises them into a single document.

Arnold's role 2: Industry investigator

Interviewing industry experts: Discussing and interviewing industry managers and experts has been Arnold's central method for getting relevant information for his projects has been discussing and interviewing managers and experts in the industry.

Drawing conclusions for the redesign of transportation: In this task, Arnold goes through the interview material, seeks relevant information and draws conclusions with the company's goals in mind.

Arnold's role 3: Member of development workshops

Generating solution alternatives: In this task, Arnold synthesizes information and ideas into solutions with certain parameters in mind and identifies, analyses and evaluates problems, which the solutions might have.

Evaluating the impact of solution alternatives on customers: Here Arnold discusses and thinks the consequences of the various solution alternatives.

Asking questions: In the process of development workshops, asking relevant questions is important for Arnold.

Explaining NEOT's situation and its goals: A major portion of the time at workshops goes to explaining knowledge and perspectives to other parties.

Convincing the other party: In the course of workshops it is at some point necessary to convince the other party to adopt some perspective or see the benefit of some aspect.

Preparing PowerPoint presentations: The workshops often involve presentation in the beginning of the event, which need to be prepared before hand. In this preparation task, Arnold chooses the appearance of the presentation, selects and writes relevant information to it and at the same time constantly evaluates the length, style and the tone of the text and appearance.

Arnold's role 4: Data analyst and operations optimizer

Recognizing improvement potential by looking at data: Here Arnold enters the company's various databases and analyses the data to find patterns that could have relevance to operation optimization.

Generating solution alternatives to exploit improvement potential: In this task, Arnold synthesizes information and ideas into solution alternatives for optimizing operations with certain parameters in mind and identifies, analyses and evaluates problems that the alternatives might have.

Arnold's role 5: Manager of the IT project system specifications

Explaining NEOT's needs: In the IT project meetings, an essential part is to explain knowledge and perspectives to other parties.

Generating specification alternatives: In this task, Arnold synthesizes information and ideas into solutions with certain parameters in mind and identifies, analyses and evaluates problems, which the solutions might have.

Asking questions about feasibility: In the IT project meetings, Arnold asks relevant questions about the feasibility of various system features.

Evaluating specification alternatives: Here Arnold discusses and thinks the consequences of the various specification alternatives.

Arnold's role 6: IT project coordinator

Requesting information from project members: Arnold has to stay up-to-date throughout the IT project and thus needs information from the other members.

Disseminating project information: As a project manager, Arnold needs to make sure that the members are up-to-date and know what is expected of them.

Delegating tasks: As a project manager, Arnold needs to make sure that the members' time, skills and other resources are well utilized to meet the goals of the project. This is achieved through delegating tasks to the members.

Organizing schedules: In order to finish the IT project in time, Arnold as a project manager needs to divide the project into parts and areas of responsibility and set deadlines for the parts.

Barney, automation engineer at Metso Corp.

Barney's role 1: Designer of automation specifications

Generating automation solutions that fulfil requirements: In this task, Barney generates automation solutions that meet the requirements he has been given

Writing documents that describe automation specification for programmers: Creating ideas and solutions is one thing, but describing them in natural language is another.

Calling for bids from subcontractors: After Barney has defined the automation specifications document he produces a call for bids document based on the specifications and sends it to subcontractor programmers.

Deciding over bid and having it approved by supervisor: After deciding over which bid is the best, Barney needs solicitation from his boss.

Barney's role 2: Requirement specifications informant

Gathering specification information relevant to automation from meetings: To create solution alternatives for the automation system, Barney needs to get information on the machine's desired properties and parameters from the other engineers and teams. This information sharing takes place in meetings.

Explaining automation's restrictions: A crucial part in engineering automation to machines is to explain automation's perspectives to the engineers and other project members.

Discussing technical details in face-to-face discussions: After the meetings a more specific discussion needs to take place, where two engineers talk over technical details.

Deciding over technical details in face-to-face discussion: The aim of the discussions is to decide over technical details that will end up in the final design of the machine.

Looking at diagrams to gain understanding: Barney and his colleagues look diagrams of the machine to gain a better understanding of the design of the machine.

Barney's role 3: Support person for programmers

Explaining in other words about specifications: Sometimes the subcontractor programmers fail to understand Barney's specifications, in which situation they contact Barney and ask for clarification.

Evaluating whether specifications can be modified in a certain way: Often the programmers' questions pertain to specifications that are for some reason undoable. When this is the case, modifications are needed.

Barney's role 4: Technical support person

Answering technical questions: Barney receives e-mails and phone calls, where mechanics, support centres or customers ask him solutions to technical problems.

Observing machines to find solutions to technical problems: If the technical question comes from the factory and Barney cannot solve it on phone, he goes to the production site to see and try the machine to find a solution.

Hypothesizing solutions to technical problems: Here Barney goes through his experience and other information in his mind about the various technical problem cases that have occurred with the machines and analyses them to come up with new causes.

<u>Barney's role 5: Tester of automation software</u>

Operating the testing device: When Barney receives an automation program from a subcontractor, he sometimes needs to test its functionality himself. In the task he needs to test the various features by operating a simulation machine.

Evaluating the functioning of technical features: Here Barney assesses the practical consequences of the potential technical feature alternatives.

<u>Barney's role 6: Project manager</u>

Evaluating, monitoring and recording costs: Project costs need to be controlled. This involves evaluating them before hand, then monitoring during a project, and in the end recording them.

Checking and approving invoices: As Barney has some budgetary power he can approve some invoices. In this task, Barney analyses the information in the invoice and evaluates, whether it corresponds to his conception of the costs and other information. For example, if the programmer has marked an 11-hour day, when he is involved in other projects at the same time, it can be considered implausible.

Asking subcontractors about details regarding to various figures: Sometimes some figures in the invoices don't make sense to Barney. Then he has to ask the subcontractor to get an explanation for the figures.

Prompting subcontractors: Occasionally subcontractors fail to report their progress or do other things that are expected of them. In such cases, Barney has to prompt them.

Barney's role 7: Observer of machines at worksites

Operating machines: It is important for the company to get information of the actual functioning of the machines at worksites. After getting at the worksite, Barney's task is to test the various machine features by operating it.

Observing machines' functioning: Sometimes Barney goes to the customer's site to see how well machines operate. As Barney triggers the machines functions, he needs to observe the machine to gather information.

Writing reports based on observations: After operating and observing a machine, Barney needs to write a report for the purpose of later R&D.

Huckleberry, customer service associate at Infotron Inc.

Huckleberry's role 1: Customer service person

Answering questions: Huckleberry receives e-mails and phone calls, where customers ask him solutions to technical and invoicing.

Escalating problems to other teams: In case the customer's problem is beyond Huckleberry's knowledge, he needs to direct them to other teams that have the know-how. For example, complex technical problems need to be solved by the technical teams and complex invoicing problems by invoicing specialists.

Hypothesizing causes of problems: In this task, Huckleberry tries to figure out causes behind customer problems.

Huckleberry's role 2: Contact person between customer service and regional marketing teams

Answering questions: In this task, Huckleberry answers to questions from customer service and regional marketing teams by phone, chat, or e-mail. Marketing teams, for example, ask him details about products, services, and invoicing.

Asking questions for another party: Sometimes Huckleberry lacks the knowledge to answer the questions himself. As a contact person, it is his task to ask his team members or the marketing teams for more accurate answers.

Explaining processes: Sometimes just an answer or detail is not enough and Huckleberry needs to explain the knowledge he has on how a process is done to people in his customer service team or marketing teams.

Huckleberry's role 3: Member of company support centre development project

Generating development ideas based on experience: By working in the customer service, Huckleberry accumulates experience on customer problems and using the company's products. He then synthesizes this knowledge to generate development ideas for enhancing the company support centre.

Using analyzing tools to build understanding on customers: To come up with better ideas how to develop the support centre, Huckleberry uses the company's analyzing tools to refine information and to get a better understanding of the customers' thinking and behaviour.

Explaining ideas and knowledge from the customer perspective in meetings: In the meetings, Huckleberry represents the customer and usability perspective and the members share ideas and knowledge about various aspects of the support centre service that they have come up with and accumulated through experience.

Evaluating development ideas: In this task, Huckleberry discusses and evaluates the consequences of his and his colleagues' various development ideas.

Huckleberry's role 4: Member of market trend analysis project

Recognizing patterns from data and information: To find causes behind market trends, Huckleberry needs to recognize patterns in market data and information.

Hypothesizing causes behind trends: This task begins by going through own experience and knowledge and recognizing patterns in market data and analyzing them in order to synthesize new potential causes for the trends.

Writing reports: Doing research on market data and trends, Huckleberry writes a report for the project team.

Gathering ideas and information from meetings: In order to conduct trend analysis, Huckleberry needs to get ideas and information on the markets from project members. This information sharing takes place in meetings.

Explaining ideas and knowledge in meetings: In the meetings Huckleberry among his colleagues share ideas and knowledge about the markets that they have come up with through experience and learning from various sources.

Wulle, societal relations associate at Businessor Inc.

Wulle's role 1: Event organiser

The purpose of Wulle's event organiser role is to make potential employees more informed about Businessor by arranging events such as excursions. As in most jobs, the event organiser role is tightly linked to other roles namely attendant at meetings role, which becomes relevant when making preparatory arrangements with the collaborators. Six tasks were extracted from this that were specific to the event organiser role:

Generating event topic alternatives: In one task of Wulle's event role, he needs to determine event topics, in which he analyses the needs and background of the student organisations and the company units in question.

Scheduling and making arrangements with student organisations: In order to find a right time for an event, Wulle needs to do scheduling with student organisations. In the task he first finds out from his organisation's calendar what times are fit for the presenting department and then contacts the student organisation and asks what times suitable for them. Through dialogue where they find compare their preferences, they agree on a particular time. Often times this is done in preparatory meetings as well.

Making premise reservation: After an agreement is made on the time of an event, Wulle needs to make sure beforehand that all the necessary premises will be there at the time of the event. By knowing the program of the event, he knows what is needed and goes to the company's system to check available premises, such as a room and a video projector, and reserves them on the given day.

Prompting: After most things are settled over and the time is nearing, Wulle prompts the student organisation to inform its members of the upcoming event and to notify him of attendance.

Choosing relevant speakers: In this task, Wulle picks appropriate speakers. He first goes through the company's common schedule to find available people who are available and ranks them in terms of relevance to the topic and competency give speeches.

Handling sudden problems: Sometimes the unexpected happens—a speaker gets sick a day before the event or a video projector does not function. This calls for handling such troubles flexibly. After receiving the information, Wulle needs to come up with an alternative way program for the event, get the information from relevant colleagues, and communicating the new program.

Wulle's role 2: Meetings attendant and coordinator

Gathering information: One of Wulle's main tasks is to gather and record opinions, ideas and information from meetings. To get the necessary information, Wulle needs knowledge of the IT business and society's needs.

Writing down agreements: Another pivotal task in the meetings is to record what the group agrees on. In this task, Wulle listens to what the participants are saying and writes down the essential parts.

Explaining what has been done and how: In this task, Wulle explains in the meetings what his employer and unit have been doing for the project.

Summing up discussion: When Wulle is in the role of coordinator, his task is to sum up the discussion in the end of the meeting at an appropriate time.

Directing discussion on project management practicalities: After the discussion has been summed up, it is time to start planning for the future of the project. In this task, Wulle chooses an appropriate time to direct the discussion towards practicalities and suggests that it is a good time to start making agreements about goals, responsibilities, and schedules.

Wulle's role 3: Project member and coordinator

Preparing agendas: Before meetings in case Wulle has the role of project coordinator, he needs to prepare a common agenda that determines topics and the order they are dealt with based on the notes he has gathered from previous meetings.

Creating project plans: In this task, Wulle puts together information from meetings and members to create a project plan for the advancement of the project, in case he has the coordinator role.

Conducting investigation on unclear subjects: When some issue remains unclear in the meeting, it needs to be clarified. When Wulle is assigned to the task, it involves contacting various parties to query whether they are willing to participate in the project, or finding out from, e.g., intranet resources or the Internet information on organisations, whether they have participated in some related projects before.

Getting information from project members: Coordinating the project demands being on top of the progress of its members. In this task, Wulle follows the project plan and schedule and contacts members to check their status.

Compiling project information and sending it to members: It is necessary to keep the members informed when coordinating a project. In this task, Wulle compiles the relevant information and sends it to the members.

Monitoring project schedules: Coordinating a project requires keeping an eye on time during it to make sure things advance in time.

Wulle's role 4: Financial administrator

Making budget forecasts: Between quarters, budgets get reviewed and cost forecasts are done to prepare new budgets for the next quarters. Wulle's task is to estimate the costs for the next quarter, which he usually does by looking at the same quarters costs last year and adding or subtracting from it, depending on the action plans for the coming quarter.

Monitoring actual costs: Costs need to be in check and it involves constantly keeping them on track.

Preparing invoices for managers to be solicited: Before a transaction can be made, the invoice related to it needs to be validated by a manager, under whose responsibility the cost centre is. The invoice needs to be prepared for the manager in the intranet. In the task, Wulle assembles the necessary information into an invoice and assigns it to the relevant manager to be approved.

Making transactions: When Wulle has gotten an approval from a manager, he can make the transaction. In this short task, he logs into the company's transaction service and fills in the necessary fields for the transaction, that is, cost centre, recipient information, sum, and due date.

Prompting managers to approve invoices: As managers are busy, they often don't find time to approve Wulle's invoices immediately. When Wulle knows that the transaction is urgent, he prompts the manager to approve the invoice.

Requesting extra funds when noticing a need: Sometimes a contribution to a project turns out to be insufficient, and then Wulle has to ask for more money either from the Finnish office or from the European headquarters. This task involves getting the information from the project team about the need for money, and then sending a request to either of the offices.

Filling forms to prevent bribery accusations: To avoid accusations of bribery when contributing money to projects, certain forms need to be filled to indicate that the transaction is not bribery. In this task, Wulle chooses the appropriate form for the current situation and fills in the fields. If he doesn't know, for example, which cost centre some sum is taken, he asks the manager of the unit.

Appendix 4: Knowledge work task categories, task types and and their respective tasks

INTERNAL: Analytical tasks

Checking and approving / disapproving (3 tasks):

- Checking language translations (Amadeus, Role: Localization person)
- Verifying document authenticity (Amadeus, Role: Direct user support person for Finnish users and companies)
- Checking and approving invoices (Barney, Role: Project manager)

Investigating (1 task):

- Conducting investigation on unclear subjects (Wulle, Role: Project member and coordinator)

Gathering data and information (6 tasks):

- Gathering relevant information from databases (Arnold, Role: Planner and organiser of tender preparation)
- Gathering and organising bids (Arnold, Role: Planner and organiser of tender preparation)
- Gathering specification information relevant to automation from meetings (Barney, Role: Requirement specifications informant)
- Gathering ideas and information from meetings (Huckleberry, Role: Member of market trend analysis project)
- Gathering information (Wulle, Role: Meetings attendant and coordinator)
- Getting information from project members (Wulle, Role: Project member and coordinator)

Monitoring (2 tasks):

- Monitoring project schedules (Wulle, Role: Project member and coordinator)
- Monitoring actual costs (Wulle, Role: Financial administrator)

Recognizing patterns and possibilities (3 tasks):

- Recognizing patterns in user data (Amadeus, Role: Developer of the automated user self-service system)
- Recognizing improvement potential by looking at data (Arnold, Role: Data and operations analyst)
- Recognizing patterns from data and information (Huckleberry, Role: Member of market trend analysis project)

Scheduling (2 tasks):

- Organizing schedules (Arnold, Role: IT project coordinator)
- Scheduling and making arrangements with student organisations (Wulle, Role: Event organiser)

Testing programs (1 task):

- Testing the system (Amadeus, Role: Developer of the automated user self-service system)

Using analyzing tools to create information and insights (2 tasks):

- Using statistics to verify hypothesis (Amadeus, Role: Developer of the automated user self-service system)
- Using analyzing tools to build understanding on customers (Huckleberry, Role: Member of company support centre development project)

Visual analysis (4 tasks):

- Interpreting visual information of job applicants (Amadeus, Role: Job applicant evaluator)
- Looking at diagrams to gain understanding (Barney, Role: Requirement specifications informant)
- Observing machines to find solutions to technical problems (Barney, Role: Technical support person)
- Observing machines' functioning (Barney, Role: Observer of machines at worksites)

INTERNAL: Synthetical tasks

Evaluating and deciding (11 tasks):

- Evaluating and deciding over job applicants (Amadeus, Role: Job applicant evaluator)
- Drawing conclusions for the redesign of transportation (Arnold, Role: Industry investigator)
- Evaluating the impact of solution alternatives on customers (Arnold, Role: Member of development workshops)
- Evaluating specification alternatives (Arnold, Role: Manager of the IT project system specifications)
- Deciding over bids and having them approved by supervisor (Barney, Role: Designer of automation specification)
- Evaluating whether specifications can be modified in a certain way (Barney, Role: Support person for programmers)
- Evaluating the functioning of technical features (Barney, Role: Tester of automation software)
- Evaluating, monitoring and recording costs (Barney, Role: Project manager)
- Evaluating development ideas (Huckleberry, Role: Member of company support centre development project)
- Choosing relevant speakers (Wulle, Role: Event organiser)
- Making budget forecasts (Wulle, Role: Financial administrator)

Generating ideas and alternative solutions (11 tasks):

- Generating solutions for back-up systems (Amadeus, Role: Developer of the automated user self-service system)
- Devising stipulations for tender (Arnold, Role: Planner and organiser of tender preparation)
- Generating solution alternatives (Arnold, Role: Member of development workshops)
- Generating solution alternatives to exploit improvement potential (Arnold, Role: Data and operations analyst)

- Generating specification alternatives (Arnold, Role: Manager of the IT project system specifications)
- Generating automation solutions that fulfil requirements (Barney, Role: Designer of automation specification)
- Generating solution alternatives to problems (Huckleberry, Role: Customer service person)
- Generating development ideas based on experience (Huckleberry, Role: Member of company support centre development project)
- Generating event topic alternatives (Wulle, Role: Event organiser)
- Preparing agendas (Wulle, Role: Project member and coordinator)
- Creating project plans (Wulle, Role: Project member and coordinator)

Hypothesizing (4 tasks):

- Hypothesizing causes of problems (Amadeus, Role: Member of Site operations team)
- Hypothesizing solutions to technical problems (Barney, Role: Technical support person)
- Hypothesizing causes of problems (Huckleberry, Role: Customer service person)
- Hypothesizing causes behind trends (Huckleberry, Role: Member of market trend analysis project)

EXTERNAL: Communicative tasks

Answering questions (7 tasks):

- Answering technical questions (Amadeus, Role: Member of Site operations team)
- Answering technical questions (Amadeus, Role: Direct user support person for Finnish users and companies)
- Answering questions (Amadeus, Role: Contact person)
- Answering technical questions (Barney, Role: Technical support person)
- Answering questions (Huckleberry, Role: Customer service person)
- Answering questions (Huckleberry, Role: Contact person between customer service and regional marketing teams)
- Filling forms to prevent bribery accusations (Wulle, Role: Financial administrator)

Delegating (3 tasks):

- Delegating customer problems (Amadeus, Role: Contact person)
- Delegating tasks (Arnold, Role: IT project coordinator)
- Escalating problems to other teams (Huckleberry, Role: Customer service person)

Directing discussion (2 tasks):

- Directing discussion in job interviews (Amadeus, Role: Job applicant evaluator)
- Directing discussion on project management practicalities (Wulle, Role: Meetings attendant and coordinator)

Discussing and deciding together (2 tasks):

- Discussing technical details face-to-face (Barney, Role: Requirement specifications informant)
- Deciding over technical details in face-to-face discussion (Barney, Role: Requirement specifications informant)

Information disseminating (2 tasks):

- Sending tendering document to firms (Arnold, Role: Planner and organiser of tender preparation)
- Disseminating project information (Arnold, Role: IT project coordinator)

Explaining knowledge (14 tasks):

- Explaining issues (Amadeus, Role: Contact person)
- Explaining NEOT's situation and its goals (Arnold, Role: Member of development workshops)
- Explaining NEOT's needs (Arnold, Role: Manager of the IT project system specifications)
- Writing documents that describe automation specification for programmers (Barney, Role: Designer of automation specification)
- Explaining automation's limitations (Barney, Role: Requirement specifications informant)

- Explaining in other words about specifications (Barney, Role: Support person for programmers)
- Writing reports based on observations (Barney, Role: Observer of machines at worksites)
- Explaining processes (Huckleberry, Role: Contact person between customer service and regional marketing teams)
- Explaining ideas and knowledge from the customer perspective in meetings (Huckleberry, Role: Member of company support centre development project)
- Writing reports (Huckleberry, Role: Member of market trend analysis project)
- Explaining ideas and knowledge in meetings (Huckleberry, Role: Member of market trend analysis project)
- Writing down agreements (Wulle, Role: Meetings attendant and coordinator)
- Explaining what has been done and how (Wulle, Role: Meetings attendant and coordinator)
- Summing up discussion (Wulle, Role: Meetings attendant and coordinator)

Persuading and negotiating (2 tasks):

- Convincing the other party (Arnold, Role: Member of development workshops)
- Requesting extra funds when noticing a need (Wulle, Role: Financial administrator)

Prompting people (3 tasks):

- Prompting subcontractors (Barney, Role: Project manager)
- Prompting (Wulle, Role: Event organiser)
- Prompting managers to approve invoices (Wulle, Role: Financial administrator)

Requesting information (9 tasks):

- Asking questions for another party (Amadeus, Role: Contact person)
- Asking job applicants questions (Amadeus, Role: Job applicant evaluator)
- Interviewing industry experts (Arnold, Role: Industry investigator)
- Asking questions (Arnold, Role: Member of development workshops)
- Asking questions about feasibility (Arnold, Role: Manager of the IT project system specifications)

- Requesting information from project members (Arnold, Role: IT project coordinator)
- Calling for bids from subcontractors (Barney, Role: Designer of automation specification)
- Asking subcontractors about details regarding to various figures (Barney, Role: Project manager)
- Asking questions for another party (Huckleberry, Role: Contact person between customer service and regional marketing teams)

EXTERNAL: Operative tasks

Handling sudden problems / fire fighting (1 task):

- Handling sudden problems (Wulle, Role: Event organiser)

Making changes in systems (3 tasks):

- Making changes in the system (Amadeus, Role: Developer of the automated user self-service system)
- Making premise reservation (Wulle, Role: Event organiser)
- Making transactions (Wulle, Role: Financial administrator)

Operating machines (2 tasks):

- Operating the testing device (Barney, Role: Tester of automation software)
- Operating machines (Barney, Role: Observer of machines at worksites)

Compiling documents (4 tasks):

- Compiling a formal tendering document (Arnold, Role: Planner and organiser of tender preparation)
- Preparing PowerPoint presentations (Arnold, Role: Member of development workshops)
- Compiling project information and sending it to members (Wulle, Role: Project member and coordinator)
- Preparing invoices for managers to be approved (Wulle, Role: Financial administrator)