MASTERARBEIT

Titel der Masterarbeit

„Industry 4.0 Based Supply Chain Management with Special Consideration of Automatic Negotiation“

verfasst von

Katarzyna Dominika Rottermund

angestrebter akademischer Grad

Master of Science (MSc)

Studienkennzahl lt. Studienblatt:	A 066 914
Studienrichtung lt. Studienblatt	Masterstudium Internationale Betriebswirtschaft
Betreuer:	O.Univ.Prof. Dipl-Ing. Dr. Richard F. Hartl

Wien, 2015

Content

List of Figures

List of abbreviations

SCM	Supply chain Management
SC	Supply chain
IT	Information Technology
RFID	Radio Frequency Identification
MAS	Multi-Agent System
CPS	Cyber Physical System
IOT	Internet of Things
EDI	Electronic Data Exchange
TP	Transport Partner
FTL	Full Truck Load
LTL	Less Than Full Truck Load
ATO	Available to Promise
D	Dispatcher
TP	Transport Partner

1 Introduction

This work is focusing on the “fourth industrial revolution”, a concept triggered by Hannover Fair in 2011 and launched by the German Federal Ministry of Education and Research in 2012, which called up for investigations related to this topic by the publication of “Recommendations for implementing the strategic initiative INDUSTRIE 4.0”. So called Industry 4.0 is a somehow futuristic concept to be realistically implemented not earlier than in 2030 according to the field experts[1], nevertheless is carrying a great potential to be explored in this work.
This thesis aims is to describe the concept, names various issues related to this subject, underlying challenges and future perspectives. Special consideration has been put on the area of the supply chain management, where various processes can be improved through Industry 4.0 philosophy implementation. Moreover, section four of this work engages itself with the automatic negotiation, since Industry 4.0 is heavily based on artificial intelligence, automation and multi-agent systems (MAS). It will be discovered how various supply chain partners can intelligently communicate between each other and optimize some processes. Focus will be put on automatic negotiation in the buyer-seller environment followed with some practical example from the field.

The paper is organized as followed: first general knowledge about the Industry 4.0, its elements and ideology will be presented naming reasons, advantages, implementation obstacles and requirements on the systems incorporated. In the further parts the Industry 4.0 in the supply chain management will be explored showing how strategic- and tactical decisions and operations might be influenced. The section three finishes with a brief description of the first examples from the practice where Industry 4.0 has been applied. The following section concentrates on the multi-agent systems and automatic negotiation describing characteristic of MAS, its architecture, negotiation process with special consideration of the agent negotiation in the transport management environment. This chapter focuses on the maximization of the negotiation outcomes between the parties

[1] Information obtained by a personal contact with Dr. Dieter Wegener, Head of Technology, Industry Sector der Siemens AG on Industry 4.0 Conference, 21.11.2014 in Passau, Germany

explaining how such a negotiation could look like, which has been supported with various examples and a development of an incremental model over the multi-criteria decision making. This thesis finishes with some challenges that need to be overcome before a successful concept implementation could be launched where a comprehensive critics has been included.

Einführung

Diese Arbeit beschreibt die "vierte industrielle Revolution"- ein Konzept, das während der Hannover Messe 2011 geboren und durch das Bundesministerium für Bildung und Forschung Deutschlands im Jahre 2012 dank der Publikation von „Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0“ ins Leben gerufen wurde. Sogenannte „Industrie 4.0“ ist ein Projekt, dessen Potenzial insbesondere für supply chain management Bereich in dieser Arbeit untersucht wird.

Ziel dieser Arbeit ist es, Industrie 4.0 zu forschen und zugrunde liegenden Herausforderungen und Zukunftsperspektiven zu beschreiben. Der Fokus wird insbesondere auf supply chain management Bereich gelegt, wo verschiedene Prozesse durch die Implementierung von Industrie 4.0 ein Verbesserungspotenzial aufweisen. Außerdem befasst sich der vierte Abschnitt dieser Darlegung mit der automatischen Verhandlung, da Industrie 4.0 sehr stark auf künstlicher Intelligenz und Multiagentensystemen (MAS) basiert. Es wird weiterhin beurteilt, inwieweit die Lieferkette auf eine intelligente Weise optimiert werden kann und eine effiziente Kommunikation zwischen verschiedenen Agenten zu unterstützen ist. Der Schwerpunkt wird auf die automatische Verhandlung, die mit einem Praxisbeispiel erläutert wird, gelegt.

Diese Arbeit ist organisiert wie folgt: erstens wird das allgemeine Wissen über die Industrie 4.0 systematisiert und dargestellt, zweitens werden verschiedene Elemente und Ideologie von Industrie 4.0 unter Angabe von Beweggründen für die Umsetzung, Vorteile, Herausforderungen und Systemanforderungen dargestellt. In den weiteren Teilen wird es bewiesen, wie die strategisch-taktische Entscheidungen und Operationen in supply chain management unter der Industrie 4.0 beeinflusst werden können.

Der nächste Abschnitt liefert eine umfangreiche Darstellung von den ersten Praxisbeispielen aus der Wirtschaft, wo Industrie 4.0 bereits angewandt wurde. Das darauffolgende Kapitel konzentriert sich auf die Multiagentensysteme und die automatische Verhandlung unter besonderer Berücksichtigung von Verhandlungen zwischen Agenten in der Verkehrsmanagementumgebung. Dieses Kapitel fokussiert sich auf die Maximierung der Verhandlungsergebnisse zwischen den Parteien und versucht anhand von einem inkrementellen Modell zu erklären, wie ein solcher Prozess aussehen kann. Diese Arbeit endet mit einigen Herausforderungen, die zu überwinden sind, bevor das Industrie 4.0 Konzept erfolgreich umgesetzt werden kann und schließt mit einer umfassenden Kritik ab.

2 Research area: shaping the Industry 4.0 approach

In this chapter all the relevant information about the Industry 4.0 will be summarized. It is necessary to explain some background leading to the approach as well as define basic elements that are creating the Industry 4.0 concept such as Internet of things, big data or smart factory. Moreover, some reasons for the Industry 4.0 implementation accompanied by the various advantages are going to be elaborated.

2.1 Business environment push to create a new concept

Nowadays, customers require flexibility, faster supply, individualized products, so that companies are forced to shorten the production cycles and react faster to the market changes. Moreover, since we leave in the era of mass customization, which allows to benefit from mass production principles while meeting individual customers' needs for personalized products at the same time[2], we have to adapt new concepts to face the globalized economies and combine standardized production processes with individualization. Increasing pressure on the producing companies, offensive towards the variant diversity, cost pressure, guarantee of the required flexibility and high demand volatility creates a push to respond faster to customers' requirements. Adaptation to that changes is found as being crucial for a successful producing company in today's turbulent environment.[3]

In order to improve the reaction speed various systems have been introduced. Before we heard about the Industry 4.0 and cyber physical systems the concept of the multi-agent systems (MAS) has been elaborated in the literature. Consequently, supply chain management (SCM) activities have always been connected with the information technology (IT) improvements, which are now facing the trend towards auto-identification by using RFID (radio frequency identification), bar codes, tags, magnets, smart labels etc.[4] Other

[2] (Ng, Scharf, Pogrebna, & Maull, 2014)

[3] (Gronau & Theuer, 2011) p.2

[4] (Gronau & Theuer, 2011) p.11; (Bose & Pal, 2005)

devices such tablets, smartphones, electronic data interchange (EDI) create together with above mentioned Internet, MAS, IT, digitalization and mechanization principles a unique environment, which connected all together discover unique opportunities which has been popularized from the German industry as a revolutionary concept. Scientists and researchers, who were willing to combine all that principles with already existing prototypes and trends came out with the Industry 4.0 phenomenon. Application-pull and technology-push has been launched from the Federal Ministry of Education and Research of Germany and claimed Germany to be extremely well placed in order to lead the Industry 4.0 project implementation.[5] In spite of the fact, that could conclude that Industry 4.0 is actually no revolution in the narrower sense, since all the basic elements for its implementation were already existing before, it might be revolutionary for the management since new business models are required.[6]

2.2 The vision of Industry 4.0

The concept of Industry 4.0 is based on three fundamental pillars:

-cyber physical systems (CPS)

-virtualisation and

-smart factory/smart manufacturing.[7]

Industry 4.0 supposed to revolutionize the world by CPS, which are powerful and autonomous microcomputers which are wirelessly connected to each other by Internet creating the environment of Internet of things (IOT).[8] CPS can be defined as:

“open, ubiquitous systems of coordinated computing and physical elements which interactively adapt to their context, are capable of learning, dynamically and automati-

[5] (Kagermann, Wahlster, & Helbig, 2013a)

[6] Information obtained from the talk of Herbert Jodlbauer (FH-OÖ Studienbetriebs GmbH) “Impulsvortrag Industrie 4.0” on EULOG 2014 conference on 17.11.2014 at the Univeristy of Vienna

[7] Information obtained from the talk of Herbert Jodlbauer (FH-OÖ Studienbetriebs GmbH) “Impulsvortrag Industrie 4.0” on EULOG 2014 conference on 17.11.2014 at the Univeristy of Vienna

[8] (Kagermann, Wahlster, & Helbig, 2013)

cally reconfigure themselves and cooperate with other CPS (…), possess and adequate man-machine interface, and fulfil stringent safety, security and private data protection regulations."[9]

An example of CPS could be an intelligent parking assisting agent together with a road traffic management and navigating system, which in fact is already existing and does not bring any new applications. CPS can be also seen as an integration between such systems with embedded software and wireless Internet connection. CPS include not only embedded systems bus also, coordination of management processes, logistics, Internet services etc. They directly capture data and via interconnection of digital networks and provide a wide range of intelligent functionalities by having multimodal human-interface. [10]

Other examples of CPS are products, containers, facilities or materials[11], which enable that all the participating objects create a network of resources and information through intelligent connections and are able to take decentralized decisions. CPS can be also understood as individual process modules, which are characterized by programmability, huge storage capacity, communication skills resulting from sensor connections and are able in a great extend to collect data about the environment as well as react intelligently.[12] In such a way CPS platforms are created and steer the business processes and production life cycles.[13] The phenomenon of the integration of CPS with Internet has been called by the German Federal Ministry of Education and Research "fourth industrial revolution".

There is to mention that technological leaps have been called "industrial revolution" ever since, coming along with the first, second, third, and now "fourth" industrial revolution. Every concept, which has been called "industrial revolution" so far had great impact on the society and the working environment in the industry. It started in the 18th

---

[9] (Broy, Cengarle, & Geisberger, 2012)

[10] (Broy et al., 2012) p.1

[11] (Spath et al., 2014) p.23

[12] (Thaler, Czaja, & Kai-Ingo, 2014) p.5

[13] (Kagermann et al., 2013b)

century with the mechanization and introduction of water- and steam-powered mechanical manufacturing facilities, which has been called the first industrial revolution. After that in the 20th century the electrical energy has been used which we name as the second industrial revolution. The third one, in the 90's, came with the digitalization, use of electronics and IT to achieve automation of manufacturing along with hand- work replacement as well as some of the "brainwork" replacement.[14] Now, the CPS will progress in the virtualization, modernization and intelligent autonomous work management.

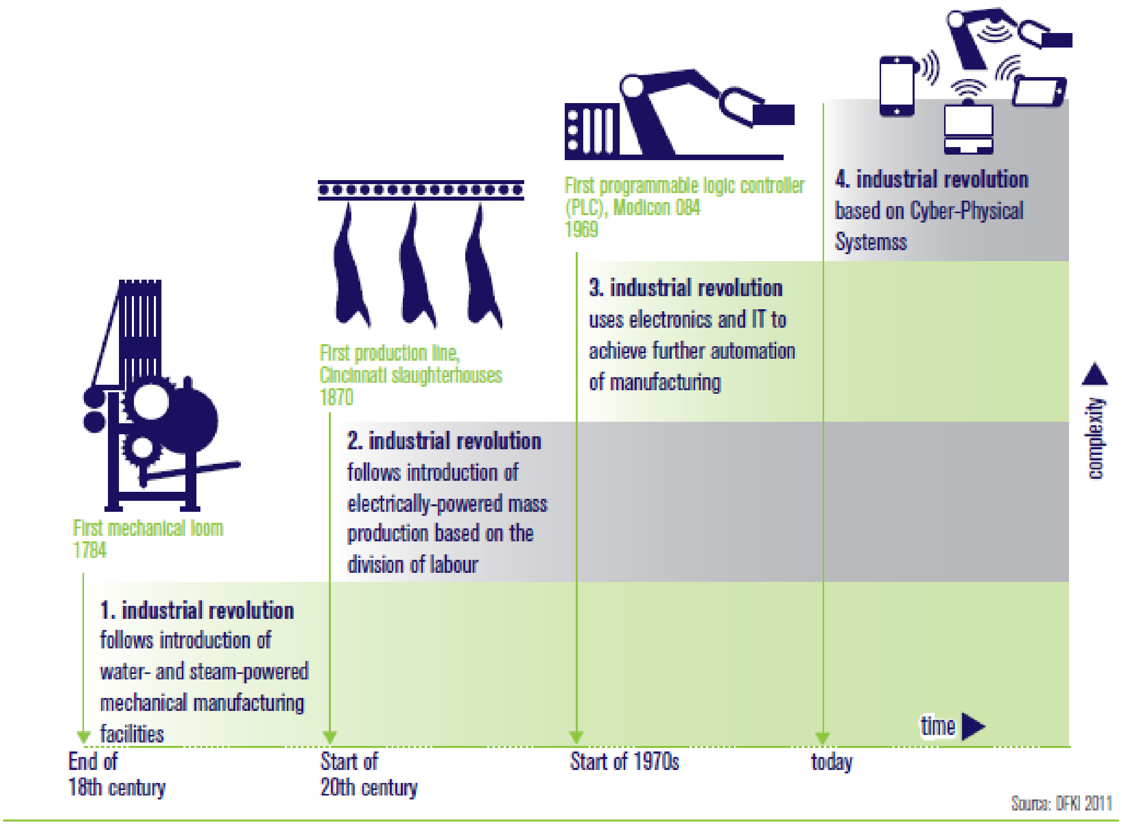


Figure 1. The four stages of the industrial revolution[15]

The potential of such a system is especially seen in the area of production control. In the centre of the Industry 4.0 principle are the "smart networks" that convert factories into "smart manufacturing systems" environment and are steering "smart machines", pro-

[14] (Kagermann et al., 2013) p.16

[15] (Kagermann et al., 2013) p.15

ducing “smart products” in “smart buildings”, connected via “smart logistics” etc. Such systems would be able to track all the production processes in every detail and enable close cooperation between the business partners.[16]

The central assumption of a German government’s vision is production in autonomous manufacturing cells, intelligent self-management, as well as automatized maintenance and servicing. At the moment no legal definition of Industry 4.0 exists, but it is necessarily connected with new organization phenomena of the supply chains and it is orientated towards satisfaction of individual customers’ needs and use of real-time data.[17]

2.2.1 Internet of Things

Surprisingly, so called “innovation of Internet of things” is not a new concept. The term itself has been used first by Kevin Ashton within a Procter & Gamble presentation in 1998, who saw already at that moment the huge potential of the RFID, which use radio waves to monitor and control the items tagged[18] in the production processing:

"*Adding radio-frequency identification and other sensors to everyday objects will create an Internet of Things, and lay the foundations of a new age of machine perception.*"[19]

Nevertheless, IOT is proclaimed a new, revolutionary concept. Under Internet of things one can understand an environment in which various cyber physical systems take their actions. Wireless connection between CPS and embedded systems create a virtual world where resources, information, objects and people create an Internet of things.[20]

---

[16] (Kagermann et al., 2013a); (Thaler et al., 2014)

[17] http://www.plattform-i40.de/presse/plattform-industrie-40/die-plattform-industrie-40-definiert-industrie-40-und-die accessed on 15 October 2014

[18] (Jamal, Omer, Abdus, & Qureshi, 2013)

[19] ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/enet/20090128-speech-iot-conference-lux_en.pdf accessed on 17 November 2014

[20] (Kagermann et al., 2013b)

In a similar manner that we are connected today with the social media, the Internet of things will connect the company's environment.[21] IOT is advertised as a future connection, consisting of many communicating "things", which have sensors and are able to act and process the data. In that way computers would be empowered "*so they can see, hear and smell the world for themselves*".[22] All the huge data captured by the sensors will be collected, clustered, analyzed and be a basis for the decision making processes.

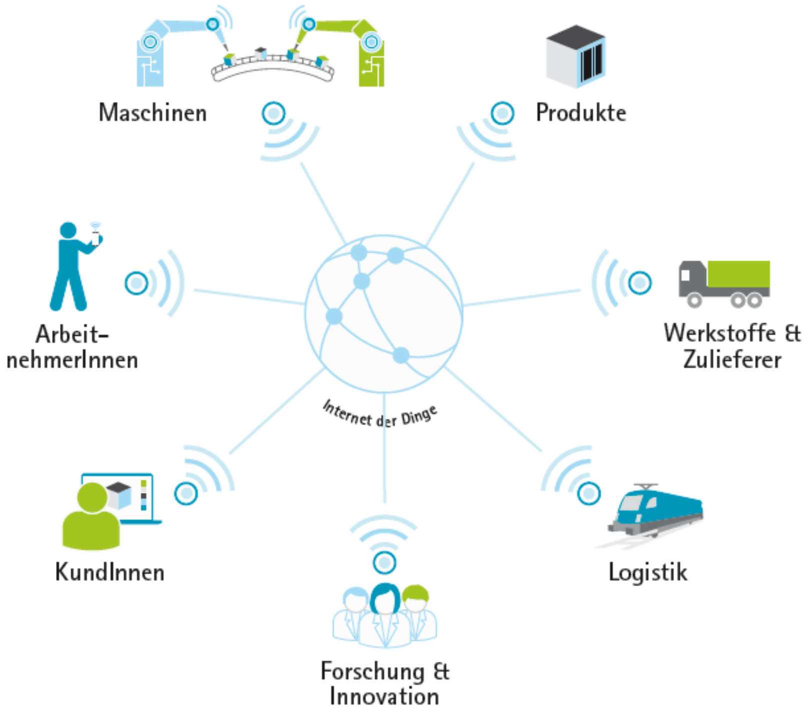


Figure 2. Graphical interpretation of Internet of things[23]

2.2.2 Big Data

According to the "big data" phenomenon the Industry 4.0 will enable to link the huge amount of the previously unlinked data which are arising from the networking of all entities involved in the supply chain processes. All that will create a huge computational cloud, from which a challenge to obtain a relevant information resulting from complexi-

[21] (Spath et al., 2014) s.46

[22] (Ashton, 2010)

[23] http://www.bmvit.gv.at/bilder/innovation/fdz/revolution.jpg accessed on 5 December 2014

ty will arise. To name an example how actually the big data is, the company Wal-Mart is producing daily 7 terabytes of operational RFID data.[24]

2.2.3 Smart Factory

The vision of the smart factory is based on the connection of the different components and devices via sensors in order to create an intelligent network called “smart factory”. Those sensors will contain all the necessary information according to the production and further processing in the entire supply chain. Such components will be able to guide themselves intelligently through the next stages which are saved in the chips acquired to the component. In such a way products become “smart” and know their way through the planned activities.[25] The smart factory describes a concept where sensitive machines and humans are supported by chips in their sensitive tasks. The smart factory is a fusion between digital, virtual and real production levels. All that enables integrated processing in manufacturing processes, sales management and services. The concept follows the modular design of the work pieces, production control through technology inspection, operation in intelligent manufacturing facilities and constant accessibility of the data needed. Those processes are able to integrate customers’ needs that can be taken into account already in the design of the value chain activities.[26]

An example of the futuristic vision of the production systems in the context of the industry 4.0 could be an order in the production, which is triggered from the customer and is navigating itself through the whole processes. First, it would have to “book” the processing steps, facilities and raw materials needed for the production. It would be able to discover all the possible errors and lateness in the production processes and organize itself possibly extra capacities resulting if any bottleneck occurs. Such as system would report to all interested parties the working progress and eventual errors or disruptions.

[24] (Jamal et al., 2013) p.81

[25] (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014)

[26] (Thaler et al., 2014) p.549

The production facilities involved in the process would be able to plan intelligently sequencing on the machines, servicing and maintenance activities.[27]

2.3 Reasons for Industry 4.0 implementation

There are several reasons to mention why the trend towards Industry 4.0 is so strong. Those reasons are seen in tendency towards modernization, flexibility, growing global competition and therefore pressure for new solutions. Worth mentioning is demographical change where society is getting older in which less young and specialized workers are available for certain jobs. Moreover, customers wants their individual requirements to be met and factories seek for detailed monitoring of activities and search for constant improvement. Furthermore, the technology push supposed to cause shorter production cycles.[28] Besides, the growing product variety and miniaturization of the lot sizes (ideally lot size one) creates in a traditional environment a huge and unnecessary working effort, which could be minimized by the de-central coordination via CPS. The same occurs in decision making process in a volatile environment, which could be enhanced via IOT.

In the future we could expect that majority the processed to be decided about would be done in ad-hoc and spontaneous manner, which again could be an argument towards IOT.[29] Without a doubt modern technologies are becoming less and less expensive every day, which is again a reason towards IOT. Additionally, ubiquitous computing is getting more popular because of wide spread of notebooks, tablets, smartphones, computer and other modern devices. Because such computing systems are being integrated in more areas of life than previously: home applications, medical devices or vehicles and they provide intelligence they could facilitate the Industry 4.0 implementation.

---

[27] (Spath et al., 2014) p.25

[28] (Spath et al., 2014) p.19; (Kagermann et al., 2013b)

[29] (Spath et al., 2014) p.20, 80-81

2.4 Industry 4.0 delivering advantages

The new concept of Industry 4.0 is expected to bring several revolutionary advantages into the industry sector, because goods would be able to move faster in the factories or along the entire supply chain due to the information transparency.

To start with, Industry 4.0 is promising changes especially in the production processes and enhancing the work giving a new speed of processing as well as efficient use of resources in a sustainable manner saving the energy use. Possible integration with other business sectors and industries (vertical integration within a company as well as horizontal integration) as well as integration of dynamic values (smart mobility, smart, logistics) would create a new phenomenal of business intelligence.[30]

One of the biggest hope in the fames of Industry 4.0 is production of batch size one, because as mentioned previously products might be tailored to the customer's needs. Because production is prone to become flexible, more efficient disturbances would be handled intelligently in real-time. Ideally, development periods might be shortened and decision making decentralized so that production would be conducted in autonomous manufacturing cells with possible ad hoc changes concerning scheduling, buffer and alternatives by avoiding idle time. However, people would be released from the repetitive assembly line work, it is proclaimed that humans would be still in the center of intelligent smart factory.

To continue with, The Federal Ministry of Education and Research of Germany identified eight potentials of the Industry 4.0. Fist of them consist of individualization of the customer requirements in design, configuration, ordering, planning and production processes, so that the batch size one would be possible. Secondly, the previously mentioned flexibility coming from dynamic work formation, quality, risks clearing and agile systems. Thirdly, optimal decisions to be found. Furthermore, productivity of the resource utilization and efficiency were mentioned. Next aspect, which is directly linked with the supply chain is the fact that the Industry 4.0 is offering new value opportunities through

[30] (Lasi et al., 2014)

new services such as downstream services. Also the response to the demographic change, work-life balance and high-wage economy were discussed.[31]

Furthermore, Acatech (Deutsche Akademie der Technikwissenschaften) lists some quite extraordinary advantages of the Industry 4.0 such as: resource preservation until 50%, production of the individual products to the costs of mass production, tailoring of the working hours on the needs of every worker. Certainly IOT possess great potential, nevertheless self-criticism and implementability analysis are crucial at this point.[32]

2.5 Implementability of Industry 4.0

There is not to doubt that the concept of industry 4.0 is subjected to many challenges since many static planning processes will become more dynamic and complex. First of all, due to increased complexity of managerial activities an open, constant communication and partner trust is required. Since Industry 4.0 and data exchange among various components connected with CPS creates a huge amount of data, it is substantial to compress and filter the information to the relevant ones creating “smart data” from the “big data”. Nevertheless, the speed might be questionable since internet infrastructures might not handle such as big computing cloud, thus higher computing power is required.

Another question is a choice of IT technology to link various products or devices. This might be bar-codes, tags or RFIDs. All of them have a different costs, and might be too expensive for some companies. Another question arises what supposed to be tagged: item or the whole pallet?[33] In case of item tagging it might be extremely costly, because less-valuable components such as screws are itself cheaper that a chip. For this alternative of pallet tagging remains to be in use, nevertheless some sensors for weights would have to be installed in order to be able to measure an actual amount of components available.

[31] (Kagermann et al., 2013b)

[32] (Kagermann, 2013) s.4; (Thaler et al., 2014) p.5

[33] (Asif & Mandviwalla, 2005) p.409

Another issue is that frequency of the communication would become unlimited and unrestricted (due to nearly zero cost of communication[34]), thus being efficient in the information chaos requires to ensure extra capacities on the telecommunication companies and finding a relevant required information in the complexity of data.

Concerning the privacy policy, companies and devices wiould report likes and dislike of the customer, which creates a data protection challenge in the era of various cybercrimes.

Last, but not least even if the companies see a huge potential of the RFID chips implementation for the purposes of tagging the uncertainty concerning the costs and benefits is harming the implementation processes. RFID technology is often technically or financially infeasible for a wide range of firms. This is observed especially in those supply chains where the processes are not rationalized or standardized. However, RFID prices are constantly falling, thy still represent a huge cost.[35] There is a need of conceptualization of chances and risk portfolio in order to eventually be able to convince many users towards the CPS implementation.[36] Moreover, even if costs of RFID chips itself could be feasible there is to calculate an additional cost of training and integration (including consultants, relocation of the stuff, hiring or maintenance contracts)[37] of the systems processes, which especially many small and medium enterprises cannot carry.

2.6 Requirements on real-time, service-based CPS

Another topic to mention when we talk about the concept of Industry 4.0 is to learn how CPS should be designed in order to efficiently fulfil their tasks.

First of all, they have to be fast enough and flexible in their planning processes. The same aspect concerns the deployment. CPS have to be reliable, compatible, support mo-

---

[34] (Lin & Lin, 2006) p.6

[35] (Asif & Mandviwalla, 2005) p.408

[36] (Gronau & Theuer, 2011) p.12

[37] (Asif & Mandviwalla, 2005) p.409

bile devices and analyze the forecasts in an adequate manner.[38] The whole system has to be scalable and be able to overcome the volatility of the processing. Moreover, the whole structure is required to be standardized, otherwise the human interaction with the systems would be difficult if not impossible. Moreover, the future vision of the perfect CPS based machine is that it would be able to be used for various purposes.[39]

Secondly, an efficient information sharing between the machines, products and supply chain (SC) stages is required. Since all the decisions would be made autonomous and independent the planning process would become extremely complex. Similar applies to various objectives of different SC participants, which have local objectives and where reaching global optimum is extremely challenging for the CPS infrastructure.

Moreover, companies possess different information which they are possibly not willing to share, so question arises how to make partners to collaborate? There is to discuss why actually companies would be willing to share their information under the Industry 4.0 paradigm if they are not willing to do it now?

Other necessary characteristic of CPS design include: stability, sustainability, controllability and mutability (option for change or development). Moreover, certain service level will be required while CPS would be challenged to solve growing number of complex problems in real-time and would have to be autonomous in their decision process, reactive and pro-active at the same time. “Self-configuration”, “self-optimization”, “self-cure” and “self-security” are essential properties of CPS.

CPS are one step further than the sensor technologies. They have to act and select the best way to do that in a multi-criterial situation where some information received might be uncertain or even contradictory. What is more, CPS are required not only to understand situational context, but also adapt it accordingly. Another aspect is that they would have to recognize and learn from the previous actions and organize themselves and evolve.[40]

[38] (Kagermann et al., 2013b); (Spath et al., 2014)

[39] (Spath et al., 2014)

[40] (Broy et al., 2012) p.9-14

The ability of interpretation of the situation in an adequate manner as well as prediction of faults, integration of rules, real-time control, continual collection, observation, selection of context data, recognition, analysis, assessment of goal and self-awareness are crucial. Moreover, coordinated processing of mass data and ability of making decision in uncertain knowledge, as well as negotiating skills under the privacy protection policies in a proactive, strategic and reliable manner are important requirements that CPS would have to carry. CPS are required to be open systems, which means to combine interoperability with software standards and portability.[41] There is also to decide about if all the devices should be connected with each other or perhaps better through other instance?[42]

Last to mention, certification and standardization are a big issue. Currently, is seems not possible to connect supply chain parties with tags, that would transfer various information since lack of standards is harming many companies again the investment. Only if a standardization would be introduced there is a chance for significant development of cyber physical systems, because otherwise early adapters of CPS could get locked into wrong standards.[43] The only example where standards are introduce already since 15 years, so that the suppliers and value chain participant can communicate in an efficient way due to data integration is the semiconductor industry. Thus, other industry branches should base their standards development of the success of semiconductor providers.[44] Without such a consensus only few first movers might be willing to take a risk and adapt CPS.

Nevertheless if all those challenges would be overcome, Internet-based standards are prone to reach a bigger success than for example EDI, which has never been widely accepted by small and medium enterprises due to various barriers.[45]

---

[41] (Broy et al., 2012) p.10

[42] (Gronau & Theuer, 2011)

[43] (Asif & Mandviwalla, 2005) p.409

[44] Information obtained from the panel discussion on the Industry 4.0 conference on 21.11.2014 in Passau Germany

[45] (Moyaux, Chaib-draa, & Amours, 2006) p.16

3 Industry 4.0 in supply chain management

This section is focusing on the Industry 4.0 applications in the supply chain management. First, it will be elaborated under which conditions supply chain could be supported by CPS. In the further part a respective analysis of certain supply chain activities will take place. It will be discovered how strategic network design and tactical decisions are prone to change under the Industry 4.0 implementation. Afterwards the influence on some selected operations will be realized finishing the chapter with real life examples from the practice where IOT already found applications.

3.1 The road to Industry 4.0 in supply chain management

First of all, it is crucial to answer to the question why it is important to apply a new concepts such as Industry 4.0 into the supply chain management activities? This is because, most of the companies see supply chain related activities as a very costly part of their businesses and thus see a huge cost reduction in the SC reconfiguration. SC is in many cases crucial for the overall business performance, thus Industry 4.0 could be potentially an answer to the challenges of modern SC and trends towards the globalization.

To start the discussion with, as already mentioned before information technologies are important enablers of an effective SCM. Modern supply chain networks are based on data analysis and technologies which might simplify those data abundance. IT in SCM pursues several goals such as: collection of information about some product characteristics, delivery of information, production details, transparency, easy access to any data in the system through wireless networks, analysis of these data and its planning activities and others.[46]

Consequently, by identifying criteria for competitiveness of the supply chain such as: volume flexibility, lead time, service level, product variety, innovativeness, improvement and by having a comprehensive knowledge about Industry 4.0 framework we could easily see what a firm can gain through the implementation of Industry 4.0 paradigm in the SC activities. Furthermore, the fundamental tradeoff of matching customer responsiveness with the cost-efficiency could be combined by implementation of those

46 (Moyaux et al., 2006) p.15

new principles. All that shows a direction where the companies could go, which is a SCM under the Internet of things.

Besides, firms have to face a huge amount of problems concerning production planning, vehicle routing and inventory management, which are known as NP-hard problems. Firms analyze those problems usually separately since all of the resulting constraints have to be satisfied. Nevertheless, those decisions are interdependent and should be discussed jointly, which makes the planning activities even harder and more complex. Separate decisions result in globally under-optimal decisions, because the best solution for one supply chain problem discussed does not often reflect the global optimum. It would be advisable to take those decisions together and conduct common planning activities taking into account conflicting and related activities[47], which might be possible under Industry 4.0 paradigm.

In addition, worth mentioning is, that nowadays in a supply chain exists a huge gap between a material- and information flow, which today never arrive together to the certain desired control point. That is why improvement of the agility of a company is a very effective tool towards the competitiveness.[48] All that could possible create a new supply chain definition, since in a traditional way of thinking we named supply chain management as a flow of product and information. Since under the IOT vision product and information flow (stored on a chip) would be joint, the supply chain definition would become obscure. The question arises if a CPS implementation would require us to rethink what actually a supply chain is?[49]

To illustrate some certain assumption resulting from CPS implementation, on the figure below in the upper part it is to see a conventional supply chain where between various information streams a human intervention on processing information (so called media disruptions) are inevitable. On the contrary in the lower part of the picture we can see how IOT would influence the current SCM environment, releasing humans from linking the activities and change their roles in the supply chain. In such a concept, the aim of

[47] (Moyaux et al., 2006) p.2

[48] (Lou, Liu, Zhou, & Wang, 2011)

[49] (Asif & Mandviwalla, 2005) p.413

CPS is to minimize human intervention, while items are being identified by the use of electronic tags.[50]

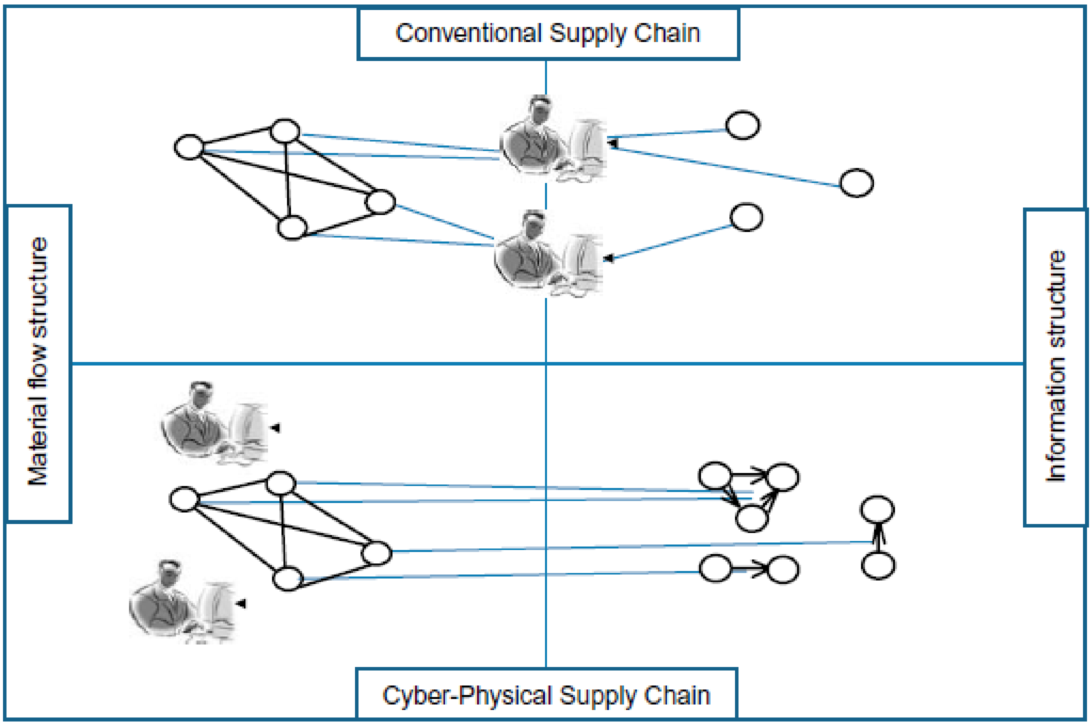


Figure 3. Supply chain of the next generation as a cyber-physical-system[51]

On the other hand, it is worth investigating under which conditions the Internet of things could be successful and profitable in the supply chain operations? This issue has its roots in the fundamental trade-off between efficiency and effectiveness which can provide opportunities for mass customization. Nowadays, this depends on the strategy, which a company might follow: either a "tailoring strategy" (mass customization), where a firm meets customers demand in producing huge variety of its products or "platform strategy", where standardized and flexible platform takes into account customers' needs incorporating the required details into the applications which can be customized. Under mass customization a company tries to postpone the decoupling point as much as possible. Nevertheless, postponement strategy refers to the productivity-flexibility trade-off, thus the later the decoupling point occurs the greater the productivi-

[50] (Asif & Mandviwalla, 2005) p.393 ;(Bauernhansl, Hompel, & Vogel-Heuser, 2014) p.78

[51] (Ivanov & Sokolov, 2012)

ty due to economies of scale. The main idea coming from IOT is that it has influence on three crucial aspects such as: asymmetric information, complexity in aggregation of information and incompleteness of information, in which a traditional SCM has to struggle with. IOT can be a valuable tool to reduce the first 2 uncertainties mentioned above. All that depends on the individual targets of the company. If only standardized items are being produced, which in reality cannot be much tailored, than the use of IOT might fail due to unnecessary infrastructure costs. Nevertheless, if there is a high demand for contextual variety observed than a “platform strategy” and IOT are more profitable.[52] Every firm by scanning its objectives and strategies should rethink and analyse the possible benefits coming from investment in IOT infrastructure.

Central vs decentral planning?

Since supply chain management under IOT reflects a typical decentralized organizational structure, at this point, there is to discuss about the advantages and inconveniences of central and decentral planning. It is vital to think if- and under which conditions decentral intelligent planning, which relates to Industry 4.0, could be better than a central planning and name various reasons for that.

First, in production and logistics the biggest challenge consists of mutability and creation of high flexible processes. The central planning brought a large extend activities, control over a huge number of various items and high utilization of the production capacities. Everything is being planned in advance starting with production parameters, personnel, machines occupancy, and material, tools and lead times. Nevertheless, since always some indeterministic disturbances could occur they usually lead to the high deviations from the plans, because centralized systems are not able to react in a flexible manner to the environmental and processing changes since a central planner is physically not able to process all the alternatives possible. This, in the complexity growing adhoc activity environment of a modern enterprise it is crucial to be able to react to those changes immediately.

From that and other reasons for dynamic organization structures a decentralized model could be in use, which could be guaranteed by CPS, so that deviations can be found eas-

[52] (Ng et al., 2014)

ier and alternatives evaluated and put into an action. To finish with, such a structure enables higher process accuracy, fast and flexible adaptation, as well as ideally self-control while interaction with other systems. Nevertheless, under this approach finding an optimal solution finds itself very difficult.[53]

3.2 How the Industry 4.0 may influence the supply chain

Through the Industry 4.0 the whole supply chain is expected to become flexible and predictable. People would be relieved from non-creative machinery activities. Moreover, increase in productivity, resource efficiency and automation are expected. Operating systems would be optimized for global needs and further automation would release different steps in complex planning processes. Ideally synergies might be realized and sequencing processes would not be hierarchically organized but integrated and synchronized and carried out autonomously.

The central motivation of integration of CPS into the supply chains is continues optimization of the processing. Such processes should respond to the discontinuous effects and react accordingly. Also forecasting and signalling of the defects in the entire systems should improve. There is to expect that such systems will allow the derivation of reliable recommendations, enable an online control of the production processes in dependence on the circulation of the real-time data and introduction of case-specific adaptive measurement strategies as well as quality assurance. Finally, reproduction of dynamic control of complex manufacturing processes is expected to arise.[54]

Nowadays, internet infrastructure enables relatively efficient information sharing along the entire supply chain. Nevertheless, this data has to be collected manually and shared between all interested parties and send to various subsystems. While in the IOT infrastructure all relevant information will be collected automatically from the data agents (smart items) which are able to aggregate, filter and share the entire business logic at the same time, quick processing of a data flow is a massive improvement compared to the

[53] (Gronau & Theuer, 2011)

[54] (Fue, 2014)

Internet-based data sharing practices. All that improves overall efficiency and effectiveness in the supply chain activities.[55]

Furthermore, auto-ID is likely to have a huge effect on every supply chain level helping to enhance demand management, automatic replenishment, customization, inventory cost reduction, out-of stock prevention, and automatic replenishment and lower the distribution costs.[56] In the next chapter an influence of the strategic and tactical decisions as well as operations will be described, underlying the biggest importance of IOT at the operational level (see figure 4).

Figure 4. The three levels of the supply chain management[57]

In order to analyse the supply chain processes and its possible improvements it is needed to conceptualize its activities. First of all, strategic long time decision are undertaken such as market research, business partner selection, capacity planning, products and technology planning. Secondly tactical (mid time horizon) decision such as master planning, inventory levels will be described and finally operations (short term planning activities) where the Industry 4.0 concept will find the most application will be analysed. Here influence on the demand planning, scheduling, procurement, monitoring and transportation will be evaluated.

---

[55] (Lou et al., 2011) p.2

[56] (Bose & Pal, 2005) p.102

[57] (Bose & Pal, 2005) p.103

3.2.1 Strategic network design

Strategic network design consists of decisions concerning the supply chain overall structure. The decisions matter SC configuration and decision which activities each stage will perform. Fundamental decision is about location and capacity planning of warehousing activities, products to be manufactured and search for cost improvement in production, transportation and distribution activities in a long-term plan preparations. Additionally, there are decision regarding customer-supplier assignment and some transportation decisions to discuss about: modes of transportation to be used, subcontracting of manufacturing, marketing strategies and price promotions or decisions regarding the information systems. What is more, long-term strategies regarding procurement, production, distribution and sales plans are being created.[58] Moreover, the role of locations, from which markets will be served and allocation of products to production or storage sites are an issue. The plan encompasses capacity decisions such as how much capacities should be allocated to each facility, which supply sources should feed each facility. As we can realize, all that decisions depend on the company's profile and are long-time horizon decisions and will not be significantly influenced from the CPS implementation. Nevertheless, it will certainly bring some vital changes in the company's environment.

First of all, a company which would decide to invest in connecting- and systems infrastructure should conduct a feasibility study under new system conditions whether it is correct for their organizations' supply chain to implement auto-ID taking into account individual company environment resulting from CPS implementation. Due to the fact that implementation of industry 4.0 concept into the SCM activities requires a huge investment one have to conduct cost and benefit analysis, sensitivity analysis, technology readiness as well as competitors' position evaluation.[59]

Accurate decisions concerning the design should be based on the trade-off between customer expectations and response speed, cost of production, transportation, storage, variety of products and investment costs. Fundamental question is if a company can de-

[58] (Chopra & Meindl, 2013) p.18-19

[59] (Bose & Pal, 2005) p.103

crease the transportation, distribution, inventory cost or significantly improve the service level through Industry 4.0 principles? All that creates for companies a necessity of rethink their previous performance and get a new look on optimization processes.

There is to suspect that thus, communication between various sites will be automatized, cross-cultural communication skills will not play such an important role as today, which can cause relocation of production sites into new "trendy" cost-saving locations. Besides, order visibility will improve, which can cause increase of outsourcing activities and specialization and therefore influence a strategic decisions regarding third-party warehousing and distribution capabilities. Furthermore, a company which has to choose an information system, will have to consolidate it with its partners and standardize the operations before CPS could be implemented. Thus, all processes would be intelligently managed via CPS possibly less excess capacity could be taken into account within strategy choice. Companies could count with positive influence on the customer service aspects such as response time, product variety, product availability, customer experience, order visibility, returnability, information and coordination, which would have to be taken into account while designing strategy.

The information transparency might imply some companies to switch their production strategies from multiple varieties production to a flexible and standardized platform that will incorporate customer personal data and expectations into various applications that can be customized in order to cover all the possible customers demand.[60]

3.2.2 Tactical decisions

Tactical SCM are based on demand forecasts and consist of business models which are adopted at the strategic level, including further planning being more detailed and accurate to achieve the maximal surplus.[61] Task of supply chain demand planning is to match external requirements (orders) with available resources (supply) in order to meet this demand in a cost efficient way. It encompasses master planning regarding how much to produce, decisions how much of inventory will be needed, creation of aggre-

[60] (Ng et al., 2014) p.1

[61](Bose & Pal, 2005); (Chopra & Meindl, 2013) p.19

gated plans for single location such as capacity level determination, production, subcontracting, stock outs and pricing issues. The planning horizon is usually weeks or months.[62]

First of all, Industry 4.0 would contribute to the improvement of forecast due to high information transparency and possibly might link all supply partners and encourage the partners to create joint forecast and production of reliable data regarding inventory, finished goods, in-transit stages or current progress in work. Within the master planning we could expect ad hoc-pull production activities. Decision how much to order on each supply chain stage would be automatically and intelligently managed and it is a vivid tool to hedge against the variability of demand. Secondly, Auto-ID might reduce those inaccuracies caused by human errors and automation in picking, shipping, docking and other consolidation operation will be error free, with increased visibility and velocity. This implies more stable planning processes and supply and demand balancing.[63]

Moreover, quantities to be distributed would not be calculated manually. Inventory planning and policies would be based on just-in time, accurate, reliable data.

Thus, unexpected situations could be discovered earlier, the buffer time to hedge against uncertainty, which is added to the actual time of the project, could be reduced.[64]

3.2.3 Operations

Without a doubt Industry 4.0 will find its most application at the operational level (see figure 5), improving the short term based decisions. Highly effective operations of a supply chain relay on the speed of information flow between the stages.[65] Since they will be automatized or semi automatized the accuracy and speed of operation is prone to improve. Moreover, some costs are expected to fall.[66]

[62] (Bose & Pal, 2005) p.102

[63] (Bose & Pal, 2005) p.104

[64] (Bose & Pal, 2005) p.103

[65] (Lou et al., 2011) p.1

[66] (Bose & Pal, 2005)

Performance attribute	Customer-facing			Internal-facing		Direct effect of Auto-ID
	Reliability	Responsiveness	Flexibility	Costs	Assets	
Delivery performance	X					Y
Fill rate	X					Y
Perfect order fulfillment	X					Y
Order fulfillment lead time		X				Y
Supply chain response time			X			Y
Production flexibility			X			N
Supply chain management cost				X		Y
Cost of goods sold				X		Y
Value-added productivity				X		Y
Warranty cost or returns processing cost				X		Y
Cash-to-cash cycle time					X	Y
Inventory days of supply					X	Y
Asset turns					X	Y

Figure 5. How Auto-ID affects supply chain operations[67]; Y=Yes, N=No

In this chapter it will be discovered how various operations such as production, scheduling, distribution transport, demand fulfilment, ATP and inventory are prone to change/improve under the IOT environment.

3.2.3.1 Production and scheduling

In production activities e-business makes companies possible to coordinate the production processes, resources allocation and alternate the due dates. The biggest change coming with IOT would be a real time track of activities and accurate optimization.[68] In operations and particularly in production "Industry 4.0" concept would certainly find the most applications, thus the production processes will be self-organized through intelligent products on intelligent machines. All activities including automatic picking, shelving, cross-docking, consolidating operations as well as error reductions will benefit from digitalization. Moreover, raw materials and parts needed at a particular point at the determined time will be easily and quickly identified.

[67] (Bose & Pal, 2005) p.104

[68] (Lou et al., 2011) p.2

Moreover, error reduction through control of track and balanced schedule would improve the productivity.[69] Through intelligent products and machines production processes would be managed in an efficient way. Moreover, all the operations on the production line such as automatic identification of components, part, finished- and semi-finished goods could be enabled during the entire production process. Additionally, idle time spend of different machines could be reduced due to possible switch in production processes, which might possibly cause increase of production output.

Internet of things would enable a vivid communication of various information between products, machines and people. Nowadays, scheduling activities on machines are determined few days before the actual production process starts creating a “frozen period” when those decision cannot be changed.[70] Wireless communication and autonomous decision aiming processes would certainly enable reduction of this period and make possible last-minute changes due to automation processes.

3.2.3.2 Distribution and transport

Looking back to the past, material flow has been shortly interpreted as transportation “from A to B”. Today this process is a more dimensional, complex management-, visualization and control operation. Execution of transports is a basic but at the same time very important task in the supply chain. Nowadays every transportation requires a minimal amount of rules to conduct it in order to optimize the material flow, avoid congestions or errors, as well as to provide an undisrupted flow of goods to the final customers. Since transportation is not only flow of goods, it is to underline its role on data transfer and sufficient documentation procedures. Hence, the real-time customer’s requirements and system reaction to disruptions and changes are of such an importance.[71]

Today’s e-procurement allows business partner to use Internet for procurement activities, negotiating, information sharing, handling transportation, warehousing, payment and documentation. Like Internet the IOT would enhance the collaboration, but the

---

[69] (Zhang, He, & Xiao, 2013)

[70] (Bose & Pal, 2005) p.104

[71] (Willibald & Hompel, 2010) p.18, 47

ubiquitous information will additionally allow to collect the real time-data of the materials purchased.[72] The usage of Internet of things might accelerate the delivery speed and accuracy along the distribution processes. Labeled cargo arriving into distribution center could be identified by reader and inform all parties of interest about the arrival. All relevant information would be stored into a database and notify the customers about eventual errors and deviations from the schedule. Information concerning the transit, arrival or delay could be distributed along the entire supply chain.[73]

Since flexibility and just-in time action pattern will dominate in the SC environment we could expect increased frequency of shipments and therefore a necessity of use hybrid transportation networks or shared use of transportation and logistics infrastructure such as: transshipment areas, goods transfer systems or distribution transportation. Required are simultaneous and accuracy of the systems reactions.[74]

Thus, some processes in receiving, picking and shipping could be automatized, we could expect a significant reduction in the labor requirement and distribution costs. Moreover, there is to expect that automatic information would be distributed when the goods arrive, so that supplier can be notified when goods arrive or run out. This ensures that customers would obtain an information about how many containers are in transit, at the transshipment destination or when they will finally arrive.[75] Finally, monitoring costs could be reduced since automatic information about the position of cargo would be distributed at any time.

3.2.3.3 Demand fulfilment and ATP

Demand fulfilment depends on the promises which are given to the customers (available to promise-ATP). When a SC visibility would be significantly enhanced obviously ATP calculation would be more accurate. Manufacturer would be able to use the real-time

[72] (Lou et al., 2011) p.2

[73] (Zhang et al., 2013), p.2657

[74] http://www.dinalog.nl/en/news/new_opportunities_for_logistics_through_cyber_physical_systems/ accessed on 12 October 2014

[75] (Zhang et al., 2013)

data for resources availability and in case of a missing goods an alternative sourcing option could be used.[76] Since sensors would be located on products and the demand information fast captured by the intelligent products, there is to expect that the demand management would not be done by humans but will be done automatically and intelligently causing automatic replenishment. Thus, supply chain partners might obtain a perfect demand- and customer's buying behavior visibility so that they will tend to order exact amounts needed.

Ordering more than actually demanded, which made companies to meet suboptimal order decisions caused by so called bullwhip effect and could be overcome thank to perfect transparency. Bullwhip effect consists of the order visibility amplification and causes a problem since the demand is being unpredictable. On the figure 6 we can see a simplified supply chain consisting of 3 actors: retailer, wholesaler and a paper mill. Retailer is selling directly to the end customer and ordering his quantities form wholesalers. Wholesaler, indeed, buys from the paper mill. The ordering behavior is similar in case of all 3 actors, but the variability (measure by standard deviation σ) is getting bigger in the upstream site.[77]

Other reasons for existing of such a negative effect are inaccurate demand forecasts, shortages in supply, batching of orders and shortage gaming. Since bullwhip effect is accompanied by extra cost payments for example in holding unnecessary inventories suffering from inefficient provision of resources, companies are searching for a vital tool to reduce it. Moreover, bullwhip effect causes higher inventory levels, due to demand uncertainty and variability. Furthermore, supply chain agility is being reduced, because of high inventory levels. This implies that companies have to sell the stocked product before they sell new products. Additionally, customer service levels are shrinking since some stockouts may occur due to lack of product availability. What is more, transportation networks become ineffective since planning processes are unpredictable

[76] (Bose & Pal, 2005)

[77] (Moyaux et al., 2006) p.3

and finally some production scheduled might be missed, because again planning activities are unreliable when the variability of the demand is high.[78]

If an information is shared across the supply chain the bullwhip effect will be stopped.[79] Under IOT product availability could be checked any time so that more accurate ATP calculations are expected. As has been mentioned before cycle time might be reduced, so that bigger demand could be fulfilled at the same time. Concerning replenishment policies, there is to expect that periodic replenishment policies will not be in use any more, since various sensors on products will give a constant information about the amount of products.

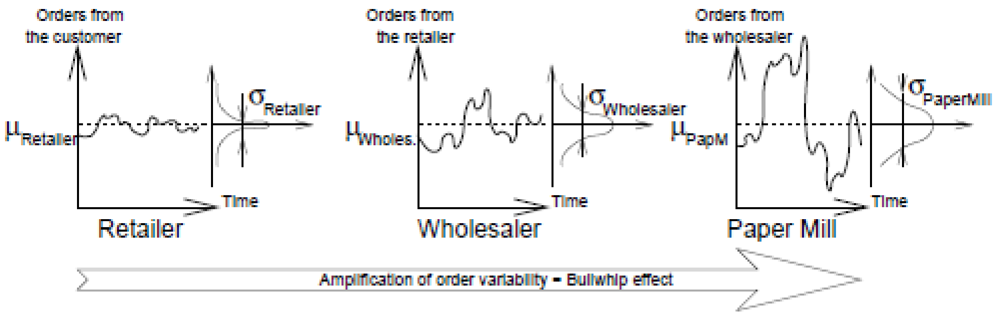


Figure 6. Bullwhip effect[80]

3.2.3.4 Inventory

New technologies enable real-time access to inventories. This implies better management and better utilization of warehousing space. Automated data collection realizes in storage inspection, information transfer and improvement of operational details such as automatic pick up, correctness of shipping and returns, mistake reduction or management or smart shelves technologies.[81]

Since, the effectiveness of the inventories depends on the accuracy of the market demand forecast the Industry 4.0 principles which significantly improve the forecast accu-

[78] (Moyaux et al., 2006)

[79] (Lin & Lin, 2006) p.5-6

[80] (Moyaux et al., 2006) p.3

[81] (Zhang et al., 2013) p.2656

racy imply improvements in the storage management.[82] Speed of data flow and automated data collection help to enhance operational aspects such as reasonable inventory control and maintenance. Paperless inventory created a unique opportunity for decision-makers regarding inventory levels accelerating speed of operations.[83] Moreover, data transparency triggers automatic identification of reorder point and replenishment through steady inventory level control, so that all the activities are becoming valid in "real-time" manner and best inventory utilization can be obtained. An ideal implementation would consist of inventory warning sensors for the warehouse, volume, type or other information needed. What is more, when a product would enter the storage an automatic warehousing list would be created which could significantly reduce the human intervention.[84] The ideal inventory model would consist of shared cooperation between all the enterprises involved in the supply chain, which sharing the common interest also share the information and risks.[85] Nevertheless, it is difficult to convince companies to be wanting to share all the information along the entire supply chain.

Inventories could be planned in a more efficient manner by using just-in time information. Therefore less safety stock would be needed since safety stock is a tool to hedge against "unknown" and volatility.

To sum up, a successful IOT implementation the area of inventory would mean automatic identification of assets entering the warehouse, quick classification of them, registration and storage list generation. Also storage time, data of the manufacturer, as well as manufacturing date, quantity would be updated by electronic tags.[86]

[82] (Tang, 2014) p.6673

[83] (Peng, 2014)

[84] (Peng, 2014) p.989; (Zhang et al., 2013) p.2658

[85] (Tang, 2014) p.6673

[86] (Zhang et al., 2013) p.2661

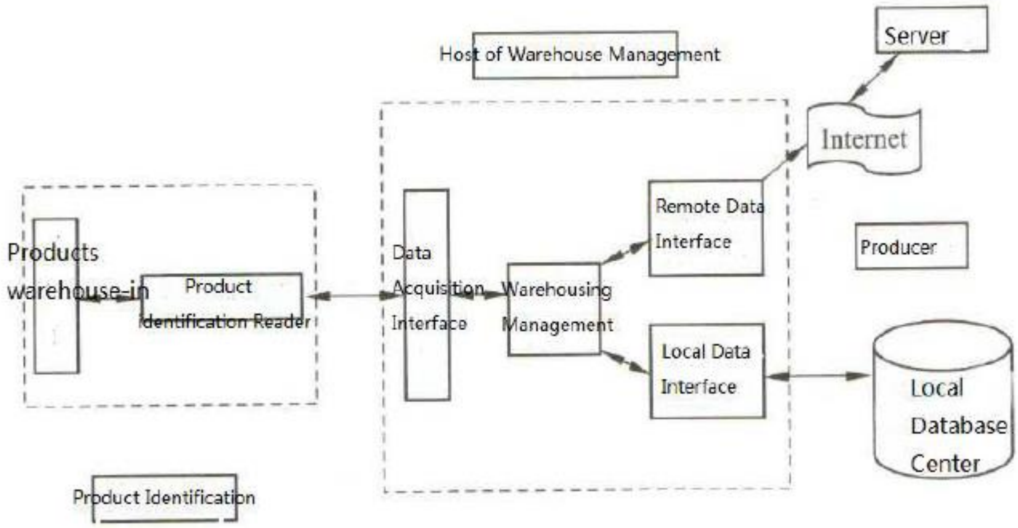


Figure 7. The structure of Automatic Storage Management based on IOT[87]

3.3 First examples from the practice

It is vital to support this paper with various examples which could illustrate the Industry 4.0 use in the production, inventories or distribution processes propagated from the companies as Industry 4.0 products prototypes.

The collection of various examples described below will sketch those improvements by presenting some general example and innovative products of various companies, which in theory could be classified as Industry 4.0 prototypes. Some companies already started do sell their products under the banner of Industry 4.0., where cyber physical systems are similar to multi-agent systems which can operate independently and conduct some activities without human intervention.

Generally speaking, as already indicated previously today's lean logistic still causes various media disruption by integration of humans to be in the centre of all the activities. The vision of the logistic of tomorrow consist of better planning, optimal decisions and automation via reduction of those media disruptions.[88] Moreover, in today's companies,

[87] (Zhang et al., 2013) p.2658

[88] (Ivanov & Sokolov, 2012) p.978; (Bauernhansl et al., 2014) p.77.78

the wall chart planning which gives information about the order number, batch size, material- and machine number is put in-and put away manually. The vision of the future is seen in a digital chart planning, which will consist of day planning, machine occupancy, order number, delays, bottlenecks which will be read from the tablets in near future. What is more, inflexible replenishment policies and material flow will be transformed into just-in-time actions and flexible change of plans according to the needs.[89]

First example from the practice in the field of cognitive logistics is a robot, called ROBOLOG, which is able to conduct an autonomous unloading of trucks or containers, without being operated by a human. Such robot has a 3D perception in high variability of objects including integration of deformable dynamic scenes in the real-time process of a truck unloading. This robot is capable to create a path plan and execute it in an adaptive manner, as well as avoid obstacles and re-plan his paths. Moreover, he is capable to handle large variety of potentially deformable items, because his sensors and environment perception is very sensitive. What is more, in accordance with the Industry 4.0 principles where human work is not being ignored his interface is suited for human operator, who can control several robots at the same time at several unloading docks in parallel, what implies an extremely efficient unloading tool.[90]

Another example in the field of transportation of goods is an intelligent container used for food transportation. For instance, a company Dole which aims to eliminate the food loses caused due to premature ripening process due to long transportation uses such containers in their supply chain. Dole is importing banana fruits from Costa Rica do European Union and unloading his products in: Antwerp, Hamburg or Helsinki. The entire journey takes at least 14 days. Transportation of the goods in such a container which is equipped with sensors that are able to capture conditions in any of the transportation boxes and indicate if a premature ripening process occurs is inevitable for a company's supply chain excellence. The big challenge that the firm is facing is that those fruits have to come to Europe in green colour, otherwise they cannot be sold further so that the importer is subjected to huge loses. Nevertheless, sensors are monitoring the circumstances of the transport such as temperature, humidity or concentration of gases,

[89] (Bauernhansl et al., 2014) p.68-72

[90] http://www.roblog.eu/ accessed on 6 of November 2014

what can exactly define in which condition the goods are. Moreover, the intelligent container can self-determinate the route, since the unloading process is not defined with First in-first out (FIFO) rule, but the container itself decides according to the condition of the boxes where the cargo is kept, where the goods have to be unloaded. Only the cargo in untouched condition and only the fruits which are still green can be send further to the proceeding unloading stations. Otherwise they have to be unloaded as soon as possible.

Such a container can also be applied in other food sectors such as meat delivery, where the intelligent container is constantly measuring the quality of meat and can at the same time be a proof for the final consumer for undisrupted temperature control, which in case of such a sensitive products as a raw meant can have a crucial aspect for the final product quality (on hour of wrong temperature can suffer in one day freshness lost in quality). This example shows an intelligent selection of items to be unloaded while loss prevention is guaranteed in the environment of CPS.[91]

Another example of Industry 4.0 use in logistics is an ORS Shuttle for storage designed from firm Knapp, which is advertised and sold under the paradigm of intelligent systems in IOT environment. This system is designed in order to conduct semi-automatic picking activities and storage system. It can prevail error-free buffering and sequencing processes and is told to be a reliable tool for replenishment of flow racks. The space-effective storage, which can be used for diverse loads can unfortunately carry only up to 50kg.[92]

Also in the area of inventories an iBin created from a company Würth is an intelligent recipient which controls the amount of goods stored and in case of shortage can automatically trigger an order. It is responsible for continuous stock detection and in an era of high customer expectations can shorten the reaction times, lower the costs or even provide a high service levels. When the recipient detects with his sensors that few products are available on hand it can automatically message customer, service or distribution

[91] http://www.intelligentcontainer.com accessed on 5 of November 2014

[92]http://www.knapp.com/cms/cms.php?pageName=glossary&iD=15&sid=5etpet9giqaepctd18pvjp79m6 accessed on 4 November 2014

centres. In fact, in extreme case it could replace the manual inventory, because it makes the whole process transparent.[93]

Several other big leading companies recognize the Industry 4.0 potential or even use it principle in the implementation activities. Example of such companies can be Bosh or McKinsey[94]. At the same time some of huge concerns use RFID within its supply chains since is not a new phenomenon. To those companies belong Unilever, United Biscuits, Motorola or Ford, Feuer Powertrain GmbH & Co. KG, Wittenstein KG, Harley-Davidson and Toyota (to monitor items for the motorcycles and automobile production[95]), baggage drop at Las Vegas airport (used for loading processes and baggage tracking) etc.[96]

Just to name another example the company Wittenstein is using the concept of decentralized control, which is tested with the RFID technology in the assembly area. This enables tracking of the current location of a parts. The information stored on the chip is defining the current behavioural and processing pattern of every single element so that the transportation activities can be planned accordingly. Moreover, the sequencing of the assembly can be determined.

Moreover, natural stone provider Antolini Luigi & C. Spa equipped his products with sensors, which give an overview about the actual storage place, so that wasteful manual inventories has been replaced and improved the inventories performance in about 20%. Quick and accurate booking of stones can be obtained.[97]

---

[93](Bauernhansl et al., 2014) p.207-220; http://vimeo.com/79034870 accessed on 5 December 2014

[94]http://www.mckinsey.com/insights/business_technology/the_internet_of_things_and_the_future_of_manufacturing accesses on 18 November 2014;

http://blog.bosch-si.com/categories/manufacturing/2013/08/the-internet-of-things-and-the-future-of-manufacturing-pchanging-value-chains/ accesses on 18 November 2014;

https://www.bosch-si.com/newsroom/iots/internet-of-things.html accesses on 18 November 2014

[95] (Jamal et al., 2013) p.79

[96](Ng et al., 2014) p.4; (Jamal et al., 2013) p.79

[97] (Gronau & Theuer, 2011) p.282

In addotion, there is a big amount of projects being implemented in Germany such as intelligent Technical Systems OstWestfalenLippe (OWL), which consists of 46 subprojects categorized in 3 groups: cross-sectional projects, innovation projects or sustainability initiatives and is currently the biggest project in the field of Industry 4.0. Just to name few of them: self-optimizing machine, human-machine interaction, intelligent networking, energy efficiency, intelligent products, forecasting or extreme fast automation etc.[98]

All those examples show that various companies or institutions perhaps try sell their already existing products under the Industry 4.0 principle or maybe just simply saw a need of future development and proclaim their products to be innovation and a response to the digitalization and the CPS grid connection. None less, there is to admit that there is observe some development of the Industry 4.0 principle and a huge potential for engineering companies to implement their ideas into various prototypical products.

3.3.1 Case study of transport disposition

In this chapter a real-life example of the first prototypical German automatic disposition system will be elaborated. The aim of this chapter is to show how a firm managed to implement the "lean" processes in the disposition of the transports, since it is a heavy human related decision area and reduction of complexity is extremely challenging.[99]

The concept of lean production has been firstly introduced in the automobile production sector. Later on, the "lean" approach has been applied to logistics, distribution, supply chain management and other areas in order to optimize processes and safe resources. Here, "lean transportation" will be implemented in the optimization of the transportation processes in the vehicle technology or routing, capacity utilization of vehicles by conduction an automatic negotiation of the multi-agent systems in the transport disposition processes as described in the previous section.

---

[98] http://www.its-owl.de/home/ accessed on 18 November 2014

[99] http://www.dvz.de/themen/themenhefte/transport-logistic/single-view/nachricht/in-spedition-ist-mehr-l accessed on 25 November 2014

Traditionally, our way of thinking about the transportation leads us to general harming conditions such as traffics or current weather situation. Nevertheless, a successful resource preserving and optimized transportation process is much more complex than those trivial reasons. Lean management, lean logistics are just slogans, which mean in the practice less empty kilometres, better capacity utilization and intelligent routing of trucks.

The project AMATRAK (Autonomous Multi-agent transportation coordination) launched in 2008 by Federal Ministry of Economics and Technology (BMWi) and Stute Verkehrs GmbH and has been inspired by necessity of process optimization, networking, sustainability and lean logistics, which characterize today's environment. Customers claiming their deliveries earlier and faster in order to reduce their inventory levels called up for innovations. Since today's company environment is depicted by process dynamics disposition managers are playing "fire fighters" at their daily work due to complexity and just-in-time requirements.

Thus, AMATRAK is an intelligent, self-controlled multi-agent system in dispositions by autonomous allocation of transport contracts to the transport partners[100] in order to release the worker's tension, facilitate processes, eliminate empty kilometres and optimize truck routs and reduce fright traffic by taking into consideration the characteristics of trailer, track capacities, load proximity and driving limits[101], which all could be seen elements towards the Industry 4.0 vision. Multi-agent software-based, self-controlling technology consisting of several independent units, which collectively solve problems aim intelligent automatic disposition and bundling truck loads to solve problems mentioned above. In the AMATRAK project customers' order data and vehicle conditions can be incorporated real-timely. Such a decentralized dynamic scheduling processes given by the software agents guarantee flexibility and more robust route planning.[102]

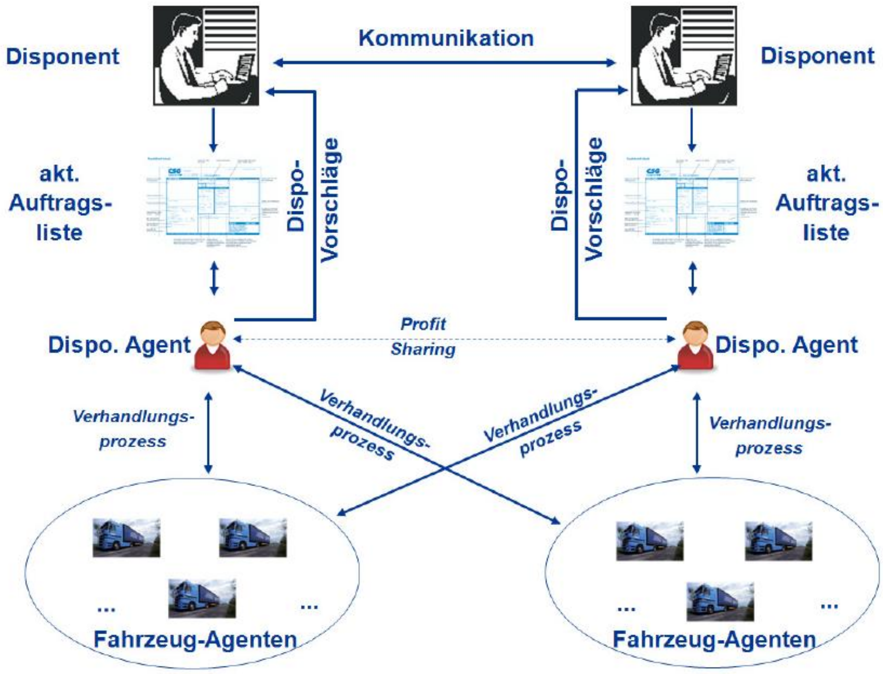
[100] http://www.logistik-heute.de/print/10043 accessed on 15 November 2014

[101] https://www.isl.org/en/projects/amatrak accessed on 25 November 2014 (document link.doc) and http://www.intelligente-logistik.org/index.php?id=amatrak accessed on 26 November 2014

[102] (Lützen, 2010)

Several expected advantages have been listed: saving in kilometers, high efficiency, better capacity utilization, fuel-and cost savings and traffic-avoidance which can be summarized as sustainable transportation[103], which are significant step towards lean transportation. In the test phase Stute Verkehrs GmbH could already confirm 6 until 11% savings in kilometers and 7 until 12% savings in average vehicle capacity utilization.[104]

Special challenge covered by the project consist of the incorporation of ad-hoc unexpected orders and disturbances in the planning processes. All the processes are based on automatic negotiations between the agents. Thus, the advantage of a decentralized and dynamic scheduling software gives a wide range of flexibility, the vehicles breakdowns or sudden orders can be incorporated in the planning, due to the fact that the system automatically generates proposals by inserting smoothly new orders into scheduling plans.[105] In that way the transport managers can save a lot of time and devote more to the customer assistance or acquisition.[106]



103 https://www.isl.org/en/projects/amatrak accessed on 26 November 2014

104 http://www.logistik-heute.de/print/10043 accessed on 26 November 2014

105 http://www.intelligente-logistik.org/index.php?id=amatrak accessed on 25 November 2014

106 (Haasis, Wildebrand, Plöger, & Zimmermann, n.d.)

Figure 8. Basic architecture and project idea of multi-agent based disposition[107]

In the first project phase the transports, which have already been distributed manually from the transport managers between the transport partners have been disposed once again by the prototypical system. The results have shown that the choice made by multi-agent systems were mostly the same as by the human booker. MAS is supposed to learn from the human as well to be given some explanation by real transport manager in case of a transport manager does not accept MAS's proposal so that the virtual truck would be punished with some penalty points in case of an incorrect choice.[108] Such a penalty system supposed to guarantee error-free MAS-based disposition based on learning from the past.

The first project phase and the prototype phase have been so much promising, so that the Stute Verkehrs GmbH planed a real implementation on their locations in the first quarter of 2015.[109] The disposition software will carry a name of iTL|Dispo and will be fully adapted to the transport manager's environment. What is more not only the own fleet but also the subcontractor will be covered by the new dispo multi-agent system and in the future even the intermodal transports will be incorporated.[110] The system will be able to dispose intelligently 100 jobs in 5 minutes, whereas 5 minutes is an average manual disposition time nowadays.[111]

As mentioned before the system is based on automatic negotiation (see previous chapter) and consists of three different agent types, which are linked to one transport manager and his transport partners. First of them is a dispatcher agent (active-m-ware), which is a software installed in the computer and supports the dispatch process. The second

---

[107] (Stute Verkehrs-GmbH & Institut für Seeverkehrswirtschaft und Logistik (ISL), 2011)

[108] http://www.logistik-heute.de/print/10043 accessed on 18 November 2014

[109] Information obtained by a e-mail contact with Dr. Kai Barwig, Mitglied der Geschäftsleitung - Geschäftsbereich Transportlogistik, STUTE Logistics (AG & Co.) KG

[110](Stute Logistics (AG & Co.)KG, 2014); http://www.logistik-heute.de/print/10043 accesses on 26 November 2014

[111] http://www.isl.org/sites/default/files/projects/amatrak/Flyer_AMATRAK_2011.pdf accessed on 5 December 2014

one, allocated in vehicle is called vehicle agent (PSV³). The last one is to find in the PC as well and called AMATRAK MAS where customer's orders are allocated and tours being computed. Moreover, each TP has a FleetBoard which is an extended version of a GPS installed in the trailer. The task of the agents is to calculate and show different possibilities concerning the feasible routes, which are displayed on the dispatcher's PC screen, nevertheless transport manager himself has to confirm the final transport allocation.[112]

On the picture below we can see on which idea the AMATRAK is based on how the infrastructure looks like:

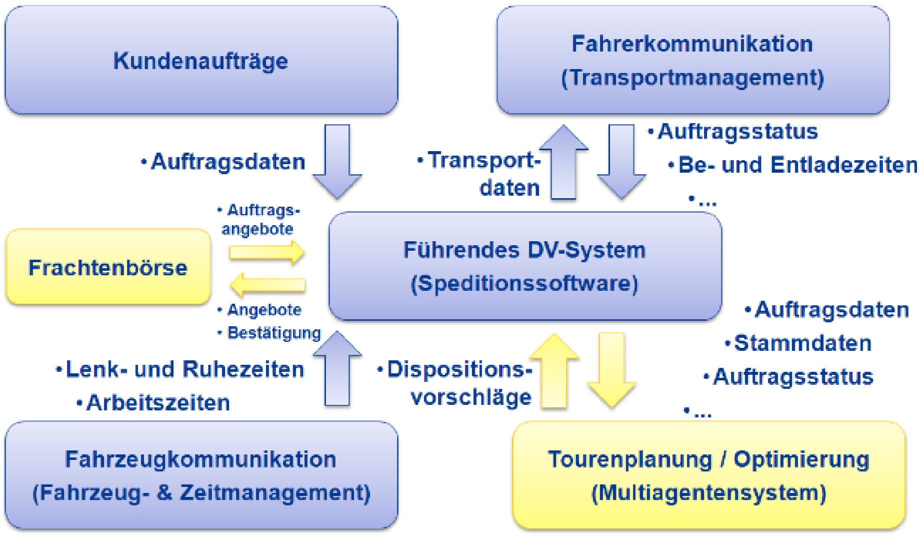


Figure 9. Interpretation of the AMATRAK structure[113]

We can observe 3 main parties involved: dispatch manager, customer and driver. Two parties of above mentioned, namely the customer and TP give information inputs to the system according to the requirements, orders, deliver times, special needs (from the customer's site) and available working time, driving times and brakes etc. (coming from the driver) as well as truck conditions, equipment (coming from the truck). The task of

[112]http://www.bestfact.net/wp-content/uploads/2014/02/Bestfact_Quick-info_efreight_3-100_AMATRAK.pdf accessed 18 November 2014; (Haasis et al., n.d.)

[113]http://www.intelligente-logistik.org/fileadmin/pdf/Abschlussveranstaltung2011/AMATRAK_AbschlussveranstaltungIL.pdf accessed on 26 November 2014

MAS is to compute the tours and communicate them via active-m-ware to the transport manager. The negotiation process is being triggered by the dispatch agent (active-m-ware), which chooses the best offer after the bidding has been completed and presents is to the transport manager. Afterwards the manager is sending a signal to PSV³ of the drivers, where relevant information are being updated and in case of some breakdowns MAS has to propose alternative solution (compare figure 10).

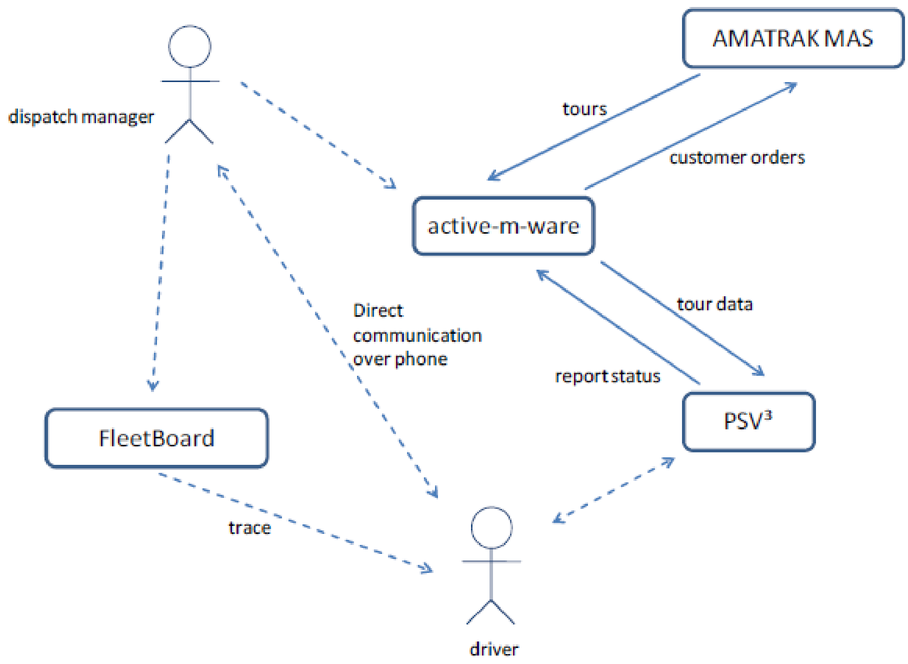


Figure 10. Interaction of the systems in a single unit[114]

The example described above suggests that, in the context on Industry 4.0 a human person is not being fully put aside in the planning activities due to often mismatch and requirement of automaic planning activities. Neverthelesss, such a system will undoubtly save time traditionally spent on matching, criteria evaluation and telephone calls on behalf of new customer's acquisition.

[114] (Haasis et al., n.d.)

3.3.2 Benefits for retailer

In this section first, a scenario will be depicted where one could understand how IOT can enhance the retailer's performance. Secondly, some general and real-case examples in the retail will be presented.

In retail supply chain management a "thing" in IOT is a transported item, which tagged by chip enables to control over the distribution and redistribution process. Usually those two distinct processes are controlled completely independently, because for now it is not possible to combine them.[115] This implies a huge potential for change for Industry 4.0 based distribution.

In terms of Industry 4.0 a store could be equipped with RFID chips and LCD displays and list a new delivery date if a products stock runs out. Customer knowing the arrival time of the desired good could potentially come back to the store and purchase the desired item. Nevertheless, a better approach where the customer is alternatively offered a discount if he places an order could be used. In case a customer decides to place an order a distribution centre would get an automatically signal and ship the good directly to the customer.[116]

For the retailers site a clear example of an advantage in a RFID equipped distribution processes is stated as followed:

"A manufacturer of soft drinks can identify with the click of a button how many containers of its soda cans are likely to reach their expiration date in the next few days and where they are located at various grocery outlets."

Similarly to other Industry 4.0 application in SCM redistribution processes can be integrated, inventory levels reduced, stocks out prevented, labor costs reduced, asset utilization improved or unsold product could be returned to manufacturer with less effort. An item removed for the shelf in retailer store could automatically send a signal for replen-

[115] (Dinge & Hille, 2013) p.1

[116] (Asif & Mandviwalla, 2005) p.19

ishment. As an example The Gillette Company claims that their retail would increase by 15% if the shelves in the sores where always stocked with accurate products.[117]

To be more precise, sensors adoption is enhanced by huge retailers such as Wal-Mart, which is saving annually approximately $8,75 billion (opposed to $3 billion initial investment) with $6.7 billion savings in labour cost reduction, $600 million in stock-out supply chain cost minimization and meeting timely delivery of goods, $575 million in theft reduction, 300$ million in tracking improvements and $180 Million in reduced inventory and carrying costs thus RFID enables rich information exchange and in case the feasibility in alliances creation with other firms and can coordinate production and distribution processes.[118]

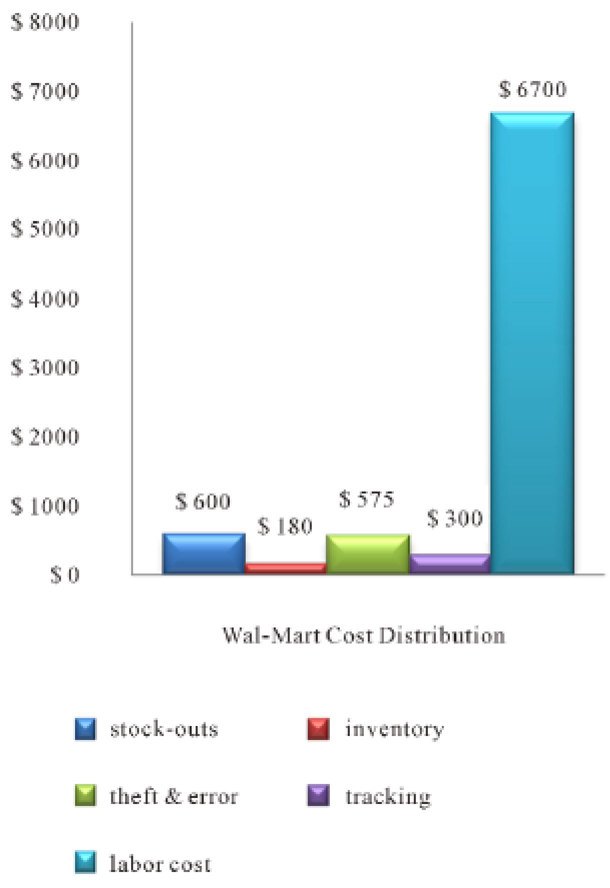


Figure 11. Annual savings obtained by Wal-Mart in different heads[119]

[117] (Bose & Pal, 2005) p.103-104

[118](Asif & Mandviwalla, 2005) p.394; (Jamal et al., 2013) p.79-80

[119] (Jamal et al., 2013) p.80

Furthermore, in a conventional store a shelf containing a RFID and a LCD display screen would indicate when a product stock runs out and when the delivery would be anticipated.

4 Multi-agent systems and automatic negotiation

In a “super connected” world of Industry 4.0 researchers and publishers focus on listing various advantages resulting from the new industrial revolution mentioning possible challenges. Nevertheless, little or no focus has been concentrated on how actually those “smart objects” will be able to communicate with each other? Technical advancement makes without a doubt such a communication feasible, but there is to analyse from the economical point of view how it can be conducted and what are the single elements of such a communication.

In this section it will be elaborated how MAS contribute to the data flow and it will be described how automatic negotiation works in the context of Industry 4.0. Special consideration will be put on how to choose extreme efficient contracts in transportation negotiation mentioned in the case study of the previous section.

4.1 What are multi-agent systems?

Multi agent systems are being used in many industries such as manufacturing, concurrent engineering, scheduling, material handling and obviously in supply chain management where MAS can organize different activities along the organization. Usually each of the components of a certain system where MAS are being implemented and controlled follows a certain goal.

The “agent” refers to the software system or a hardware, which is characterized in autonomy, social ability, reactivity and pro-activeness. The term autonomy reflects self-control and an ability to undertake actions without any human intervention. Social ability makes possible the communications between various agents and system involved humans. Reactivity is an ability that an agent is able to perceive the environment and respond real-timely to various changes. Last property, which is pro-activeness guarantees an interaction and goal-oriented behaviour.[120]

[120] (Moyaux et al., 2006)

MAS, similarly to CPS, provide collaboration in planning and synchronizing operations, where companies can make decentralized decisions regarding the planning of production, inventories, vehicle routing etc., and still satisfying various constraints. Since companies are independent and often represent different objectives, the planning process is very complex and difficult. From that reason MAS have been designed in order to create an efficient information sharing and collaboration techniques without a direct human intervention and are characterized by reactiveness and creativeness.[121] The biggest challenge for the use of MAS is seen in bilateral communication and balancing and coordination of those agents with each other.[122]

However, generally speaking MAS are less efficient than centralized solution, there is to list various advantages that characterize them. First of all, they are less complicated in terms of implementation and understanding. Moreover, centralized solution sometimes might be not possible to implement since various data and systems are coming from independent entities representing different goals. Besides, MAS can be used interdisciplinary. They are to distinguish from artificial intelligence, thus they unit the learning, planning and understanding activities instead of separately studying each of those components. What is more, MAS incorporate social ability, which has been skipped by artificial intelligence, because MAS are able to learn and plan activities.[123]

In addition, the advancing progress of the information- and communication techniques enables the sensors to be the active actors in various processes.[124] Logically such systems will pay a major if not a crucial role in the Industry 4.0 vision.

4.2 Multi-agent architecture and applications

In the context of supply chain management one or few agents of different architecture styles can be used to represent different business partners. Certainly, each of those partners represent different objectives and have different utility functions and goals to max-

[121] (Moyaux et al., 2006); (Kreinsen, 2014, 7); (Lin & Lin, 2006)

[122] (Gronau & Theuer, 2011) p.276; (Lin & Lin, 2006)

[123] (Moyaux et al., 2006)

[124] (Spath et al., 2014) p.23

imize their own profit. The agent framework is a metaphor for organizational structure, where each agent is a part of the entire decision process.[125] Since there are various types of agent there is to discuss, which type would be the best for the problem related to agent interaction between supply chain partners in the context of Industry 4.0?

There is to distinguish between 5 types of agents. Fist one is called simple reflex agent, which is realizing actions only “if” something particular happens- it works under some condition. Moreover is does not have any memory.

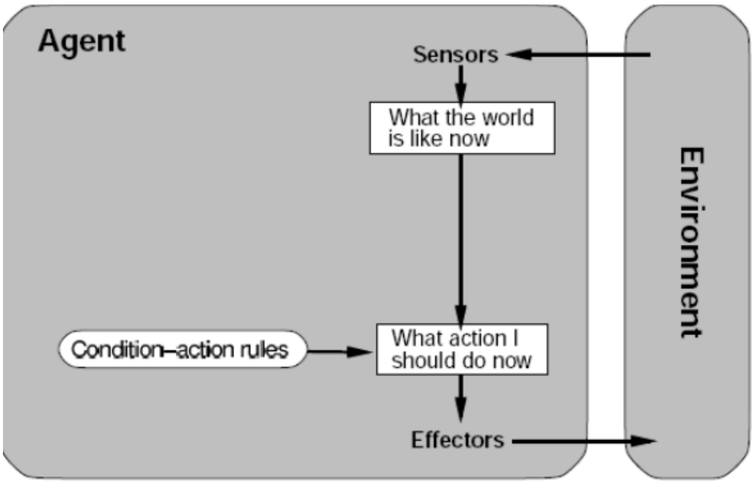


Figure 12. Simple reflex agent[126]

The second type of an agent is an “agent that keeps track of the world” characterized by internal representation of the environent in a form of “model” adopted by the agent. It also works on some condition, but this condition can only depend on the “model” of the world.

[125] (Moyaux et al., 2006)

[126] (Deshpande, Gupte, & Basu, 2006) p.41

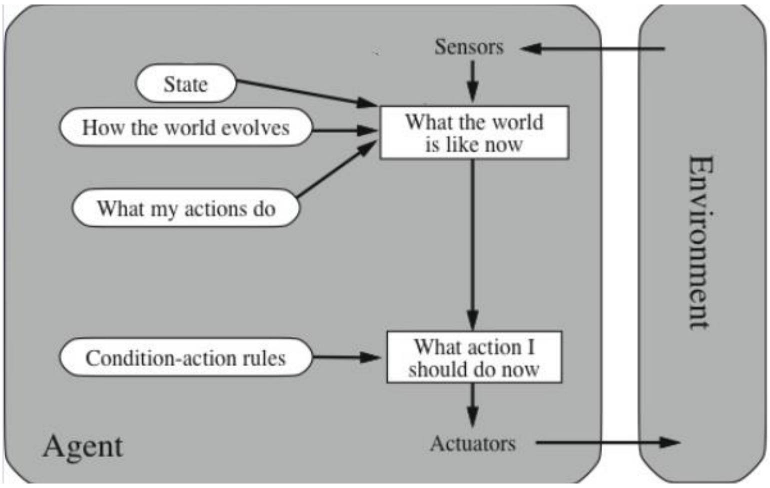


Figure 13. A reflex agent with internal state[127]

Third one a “goal-based” agent is following a goal to be satisfied, which is more close to the agent than could be applied in the Industry 4.0 based supply chain management, but not fully, since the next agent’s type is more accurate for this purpose.

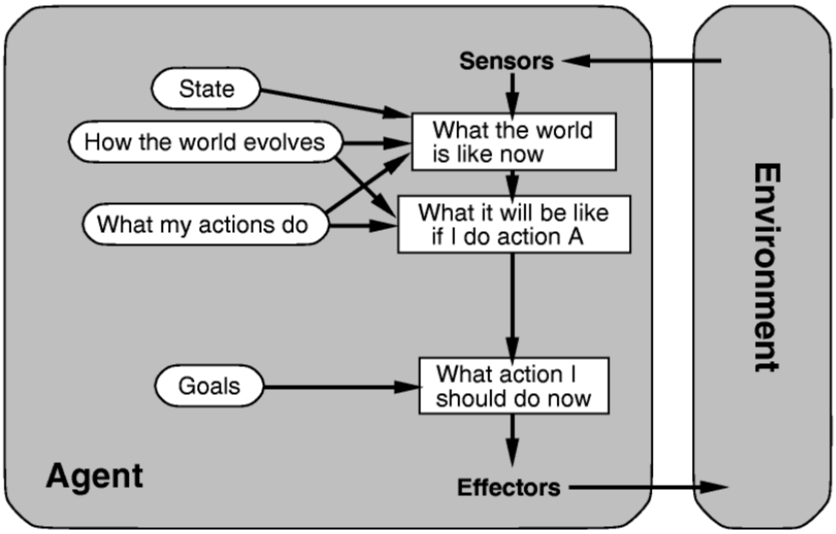


Figure 14. Goal-based agent[128]

The forth type is called a utility based agent which is similar to the goal based agent, with the difference that the agents are being programmed some utility functions. Such a function does not dictate the action plan, but shows how it is possible to increase a

[127] (Deshpande et al., 2006) p.43

[128] (Deshpande et al., 2006) p.44

utility function. This aregnt type is the most satisfactory while some metric is being given and thus is the best choice for the model desribed in this paper.

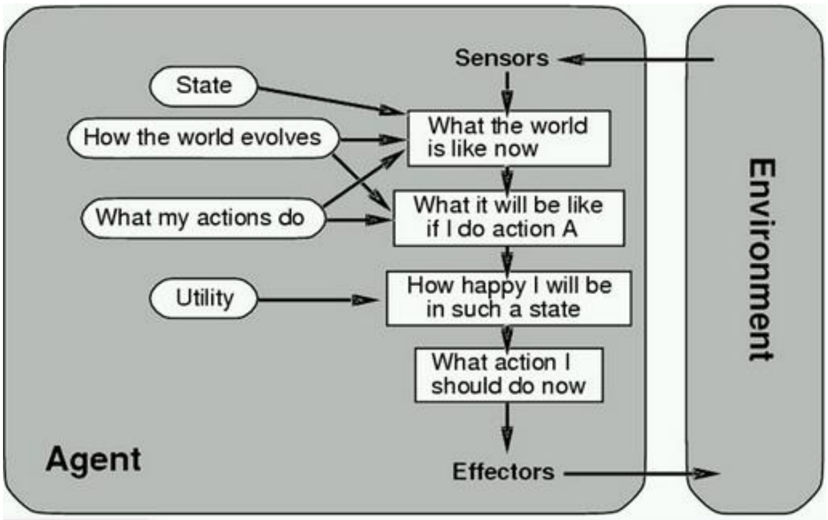


Figure 15. Utility based agent[129]

Last agent is a learning agent, whose elements could be used as well for the framework presented. Those agents can adopt to the new unknown environment and improve the future performance based on past actions.[130]

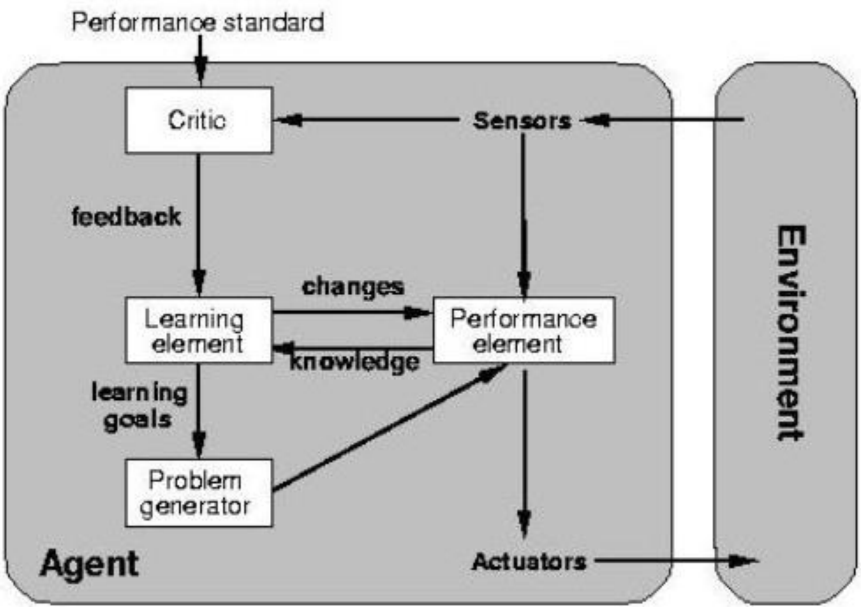


Figure 16. Learning agent[131]

[129] (Deshpande et al., 2006) p.45

[130] (Deshpande et al., 2006) p.40-45; 525-527

To mention agent's applications this technologies are broadly applied into industry. For example in Holonic Manufacturing Systems where each system component "holon" is represented by agent. Each holon is aiming to work with other holon in an efficient and scalable way. Also in process control and telecommunications agent are widely used. What is more sophisticated for the purpose of this thesis in terms of an application is air-traffic control or transportation systems. In transport the agent technology is aiming a full automation of the routing processes. Other application can be found in entertainment, commerce or medicine (games, information management, e-commerce, business process management, patient monitoring and management of the rescue team).[132]

In the supply chain consisting of various participant MAS is an instinctive choice. One supply chain partner may not have all the necessary resources to perform all the tasks alone, that is why some subtasks can be performed by few subcontractors (e.g. suppliers). Nevertheless, since suppliers are independent parties belonging to more than one supply chain, the subcontracting company does not have a full control over all the parties. At the same time he might include more than one supplier and have to choose to which one to delegate a task. Such a task is usually bounded with multiple objectives (e.g. cost minimization, quality maximization). Moreover, each task can be characterized by difference preference resulting from the objectives. In such a way a supply chain assignment problem is a multi-objective decision making problem which can be easily supported by MAS.[133]

In another approach Toskiya Kaihara assumes supply chain partner to be virtual enterprises managed in an automatic negotiation by MAS. Each supply chain participant is defined as virtual enterprise having various utility functions and N-person game theoretic approach.[134]

---

[131] (Deshpande et al., 2006) p.526

[132] (Moyaux et al., 2006)

[133] (Deshpande et al., 2006)

[134] (Deshpande et al., 2006), p.241

4.3 About negotiation

The participants of negotiation usually follow some certain interest and have their own preferences over the negotiation outcome, which can be plotted as utility function. Logically, participants try to maximize those functions, which can have various forms whereas the most common one is the additive utility function. In this utility function preferences are not influenced by changes of issue options within the negotiation. Moreover, each issue is weighted, so that the partial utilities of issues are added to each other and create a common utility function. Those partial utility functions do not have to be necessary linear. They can get a convex, concave or an exponential form. In further chapters by exploring a particular example this topic will be discussed wider and the utility functions will be graphed.[135]

What is an important remark in an automated negotiation, which will be discussed next, the participants are not eligible to change their preferences or strategies after the negotiation has started. On the contrary, in the real-life negotiation tactics can vary over the time and in the same way the scoring models (weights) of the participants over some issues can change over the time. Nevertheless, in this work there it is to assume fixed participants' preferences, because otherwise the framework would become extremely complex. This indicates as well that automatic negotiation has to sacrifice some flexibility in order to automatize the negotiation processes.[136]

When it comes to communication of participants, offers can be submitted sequentially by respecting the current negotiation round as a response, or simultaneously where the opponents do not know each other offers while sending proposals. Finally, the progress in the negotiation can be determined by improvements or concessions while submitting counter-offers, what will be discussed in this work later on.

[135] (Vetschera, Filzmoser, & Mitterhofer, 2012); (Filzmoser, 2010)

[136] (Filzmoser, 2010)

4.3.1 Different negotiation approaches[137]

In this chapter, before processing to the automatic negotiation and parctical examples, some negotiation approaches will be summarized and explained. First, the key facts concerning the axiomatic bargaining approach and strategic bargaining approach with underlying tactics will be presented. Secondly, the work will proceed with multi criteria decision making before proceeding to the chapter discussing automatic negotiation itself.

4.3.1.1 Axiomatic bargaining approach

Game theory is a branch of science that tries to explain behaviour of rational players to maximize their utilities. In this approach negotiators have to decide which alternative actions and strategies they choose to get a particular outcome. The first theory worth mentioning when it comes to the negotiation is the axiomatic approach, which defines the desirable properties of the bargaining process. Those desirable outcomes are called axioms, nevertheless this approach does not give an input into the bargaining process itself.

4.3.1.2 Strategic bargaining approach

On the contrary, strategic bargaining approach determines a set of rules and behaviours (tactics), which can be applied for a specific negotiation problem. They supposed to find the best course of actions in order to maximize the utility function of the participant.[138] This method is based on “dividing a pie” while alternative negotiation protocol is used. This approach is strictly connected to the fix assumptions. As in any other type of negotiation parties try to get to an agreement while having usually conflicting interests and preferences. For an automated negotiation strategic approach means that the agent would be programmed in the pre-determined way in order to obtain some desired outcome. Those strategies would indicate how an offer can be build and how subsequent counter-offers may look like.[139] Moreover, a strategy has to state which combination of

[137] Based on (Faratin et al., 1998); (Filzmoser, 2010)

[138] (Faratin et al., 1998)

[139] (Filzmoser, 2010)

tactics has to be used for generation of the counter-offers to the participant. According to (Faratin, Sierra, & Jennings, 1998) a weighted counter-proposal of an agent “a” to an agent “b” is a linear combination over various weights of certain tactics:

$$\Gamma_{a \to b}^{t_{n+1}} = \begin{pmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1m} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2m} \\ \vdots & \vdots & & \vdots \\ \gamma_{p1} & \gamma_{p2} & \cdots & \gamma_{pm} \end{pmatrix}$$

and his so called “mental state”, indicating intentions, goals and desires of an agent.

When V with an index “a” is a scoring function of a participant over a certain issue an offer made from “b” to “a” in time “t” would be accepted only if its scoring function in this period would be bigger than in the one in the next period t’ otherwise an agent would reject and offer. In the same way the negotiation ends when time t’ exceeds the maximum time allowed (“I” with and index “a” stays for a result):

$$I^a(t', x_{b \to a}^t) = \begin{cases} \text{reject} & \text{if } t' > t_{\max}^a, \\ \text{accept} & \text{if } V^a(x_{b \to a}^t) \geq V^a(x_{a \to b}^{t'}), \\ x_{a \to b}^{t'} & \text{otherwise.} \end{cases}$$

Now, there is to investigate why negotiators decide about a certain counter-offer. As mentioned before for building a counteroffer tactics are responsible. Such tactics being a set of functions realize the comparison of values of issues in the negotiation process, because agents are eligible to reconsider more criteria by deciding over the value of the single issue (for example the same issue can have a totally different value when the deadline approaches than at the beginning of the negotiation when plenty of time is left). (Faratin et al., 1998) identified time dependent-, resource dependent- and behavioural dependent tactics.

Time dependent tactics

This first tactics forces the players to make faster decisions when the remaining time of the negotiation is getting scarce, so that the factor which is responsible for the determination of the next counter-offer is the time. According to this tactic the participant would determine the constant, let say “α” that multiplied with the time that remains indicates the value of the next offer. In such a way “α” (α is between 0 and 1) is a factor that changes the initial offer as the deadline is approaching. If agent "a" I making an offer to agent "b" in the time "t" the value of offer for issue "j" is decreasing by α_j^a:

$$x_{a\to b}^t[j] = \begin{cases} \min_j^a + \alpha_j^a(t)(\max_j^a - \min_j^a) & \text{if } V_j^a \text{ is decreasing,} \\ \min_j^a + (1 - \alpha_j^a(t))(\max_j^a - \min_j^a) & \text{if } V_j^a \text{ is increasing.} \end{cases}$$

Resource dependent tactics

Resource dependent tactic is similar to the time dependent one, with the difference that the scarce is the resource itself (for instance money). Here, two submodels are known: dynamic deadline tactics, where the scarcer the resource is, the faster the agreement will be done and resource estimation tactics where definition of a counter-offer from a player depends on resource consumption over the time.

Behaviour dependent or imitative tactics

Behaviour dependent or imitative tactics establish a counter-offer depending on the previous offer of the opponent. Here we can distinguish between 3 submodels. In the first one, relative tit for-tat, the opponent's behaviour is imitated based on the changes put in percentage. The second one called random absolute tit for-tat and agrees on offer reduction in absolute terms (for example opponent is reducing his offer by 2 units, so that the focal negotiator would rise his offer by 2 units as well). Finally, the last one- the average tit for-tat- is about the average of percentage changes of the offers.

Example for some tactics

Giving an example for some tactics imagine an agent "a" with reservation values [0, 20] and "b" with [17, 35]. Here there is to find the second counteroffer of agent "b" to "a". Agent "a" started his opening offer with 10, "b" gave 25 afterwards, again "a" proposed 20. Being given this counter-offer of 20 the plyer "b" according to the time dependent tactics probably would offer the value of 24 since a lot of negotiating time is left. Considering the initiative tactics he would offer 20 (=25-5) to imitate the concession of the agent "a" who went down by 5 points in the previous round. On the contrary, if an agent "b" would follow the mix of time dependent and imitative tactics he could rate the time dependency with the weight of 0,75 and imitation with 0,25, thus his offer would look as followed: 0,75*24+0,25*20=23.

4.3.1.3 Multi-criteria decision making

Usually the multi issue models combine players' offer determination linked to multi-criteria decision making specific tactics (see previous chapter) over a wide range of issues. Multi criteria decision making, can be either improvement based or concession based. In an improvement based model parties start from a certain point and actively seek for Pareto- improvements, so that they finish with a more efficient outcome.[140] The second approach defines a negotiation itself as a process of making concessions to determine a contacts which would be acceptable by both parties. In this model the first offer, which opens the entire negotiation is always the most extreme one, so that the negotiator's utility would be lowered by every concession step over the time. Only counter-offers from the opponents that would provide some higher utility to the negotiator would be accepted. Here, for instance a negotiation could end not only when the time determined would pass, but also in the case if reservation value of the participant has been reached, meaning the minimal acceptable level has been exceeded.

In order to reach the optimal compromise both participants have to move along the Pareto frontier. This means in practice that they have to give up quite huge amounts of their utilities in order to raise the utility of their opponent.[141] Moreover, in this approach players might make trade-offs between various issues. Here (Faratin et al., 1998) indicated various possibilities for concession models such as: straight monotonous line, where the utility is continuously being lowered, a monotonic concession, where alternative offers of same utilities can be offered, least-cost-issue concession, where the concession is made over the issue that costs least when it comes for negotiators utility. Other more complicated concession models indicated by the authors are the lexicographic concession and tit-for-tat concession, which will not be discussed here.[142]

[140] (Vetschera et al., 2012), p.76

[141] (Vetschera et al., 2012)

[142] (Faratin et al., 1998)

4.4 *The role of automatic negotiation*

Since management of the communication flow in IOT based environment is challenging, it could be supported by MAS and automatic negotiation. Automatic negotiation as will be presented in this and further chapters is a vivid tool to show how various agents could communicate between each other and pass various information. A multi-agent systems are suitable for complex problem solving between various actors which have sometimes conflicting goals[143], where each actor would prefer a different solution and where a final agreement represents the best solution that all parties have to agree on.

In an automatic negotiation, firstly, some negotiation protocol has to be defined, where rules for interaction are being identified. The protocol covers participants, negotiation states, events and valid actions. Secondly, there is to define a set of negotiating objects that have to come to agreement within the negotiation act. Simple negotiation is based on acceptance or rejection of an offer, while agreement content is fixed. More elaborated version of negotiation accepts counteroffers and in multi-agent environment a sophisticated negotiation can include high level reasoning argumentation. Moreover, in order to conduct an effective negotiation the agents must have some beliefs (or so called mental state)[144] and all parties must clearly understand the objectives and rules. One of the most challenging aspect of the multi-agent software design that can by applied for negotiating purposes is an accomplishment of desired goal with minimum communication required.[145]

To mention the negotiation design (see figure 17) we could classify the negotiation protocols into 3 typologies that conduct various tasks. First of all the "structure identification" which first analyses the problems to be solved. Secondly the "meta negotiation protocol" is responsible for communication between the agents including interaction frequency and content, as well as negotiation flow, process duration and solution sub-

[143] (Chen, Peng, Finin, & Labrou, 1999) p.1

[144] (Faratin et al., 1998)

[145] (Nigro, Bruccoleri, & Perrone, 2006)

mission rules. Last one is called “negotiation dynamics” and encompasses offers and counter-offers evaluation and overall utility.[146]

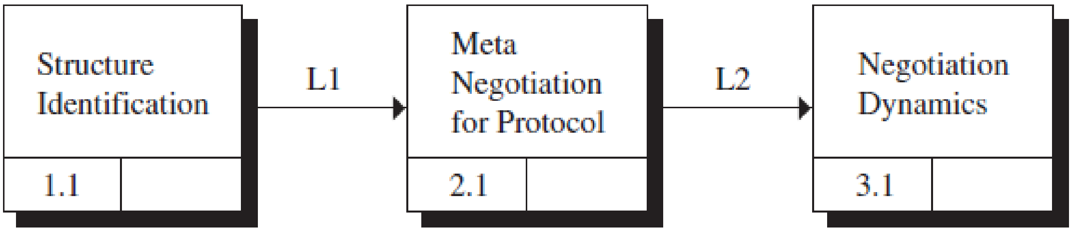


Figure 17. Negotiation design[147]

Considering the Industry 4.0 based supply chain such a structure could be applied in order to maximize the entire supply chain surplus over the local goals. Nevertheless, this, on the other hand, obviously this could seem counter-productive for some supply chain participants aiming to maximize only their own utilities.

4.4.1 Negotiation sequence

Imagine there are two parties that participating in the negotiation: dispatcher and the transport partner. Every of those two actors can be characterized by a buyer’s or seller’s role, which are changing in accordance to who is giving a (counter-) offer at a time. It means that in the first stage an automatic agent put himself in a role of seller trying to “sell” the order to the transport partner giving offers. As soon as the transport partner gives a counteroffer, the roles are changing and a transport partner would take over the seller’s role offering price for his services and an agent would either accept it or reject and so one. Important remark is that the dispatcher would negotiate in that way with various transport partners over various issues at the same time in order to identify the most efficient contracts. Actor’s variable update (see figure 18) means the necessity of the information accuracy updates before the negotiation can be completed since in the constantly changing environment information have to be updated until the last minute before an assignment can take place. This would for example mean that a planned truck has not been unloaded, so that the agent would have one partner less to negotiate with.

[146] (Nigro et al., 2006) p.3749-3750

[147] (Nigro et al., 2006) p.3750

In the final stage the "object" (see figure 18), which is transport assignment, has to be completed, so that the negotiation can finish.

The negotiation sequence of events can be summarized is a simplified way as followed:

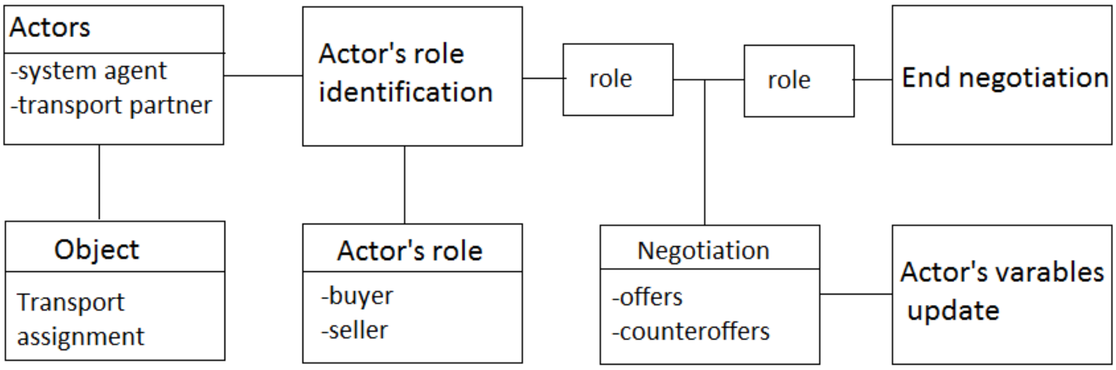


Figure 18. Own interpretation on the negotiation sequence[148]

Moreover, there are two views, which could be represented in case of transport- customer order assignment. First one is a static approach, which appoints *a prori* regular customers and regular transport partner, which is very often met in the practice where such a high level solution imposes constraints on lower levels. Nevertheless, from the economical point of view usually not optimal. The second approach based on dynamic principles represents an assignment fixed on current exogenous and endogenous conditions, where there are no such preferences.[149]

The same can be applied in the negotiations between various supply chain partners. For example, after planning long-term activities a medium-term tactical aggregate production plans will take place and finally finishing with operational short-term plans. In case of the supply chain information available at every level would differ since the time horizon is changing and at the same time data availability and accuracy. In our example transportation assignment is rather rooted on short-term decisions and conducted ad-hoc, which nevertheless does not exclude some necessities for re-planning (actor's variables updates- see figure 18).

[148] Based on (Nigro et al., 2006) p.3754

[149] (Nigro et al., 2006) p.3746

According to the example of transportation discussed here the previously mentioned “structure identification” (see figure 17) is characterized by analysis of the overall structure: transports and customers to be assigned to each other. Moreover, in the “structure identification” issues, objects and actors are given numbers, roles, typologies and characteristics and at the same time relationships between negotiations are being defined.

On the level of “meta negotiation protocol” the communication itself and communication channels including all the relevant information have to be identified. It is to specify, how, what and how often is going to be communicated and recognition when the entire negotiation process is finished (happening when the latest transport capacity has efficiently been assigned to the customer).

Last protocol (“negotiation dynamics”) is responsible for evaluation of all the aspects and giving assignment proposals, delivering counter-proposals which have to be accepted or rejected by the transport manager in the further step. Here some aspects such as: working time including daily/weekly brakes, trailer condition that have to be in accordance to customer’s requirement (minimum amount on safety belts, strut bar if necessary, truck capacity, length, height or-, as an example, delivery of an unspotted trailer in case of hygienic transports) as well as certifications for special transports have to be respected while negotiation takes place. Moreover, some traffic regulations in accordance to weekends or holidays and routes optimization by minimization of empty kilometres are to be included.

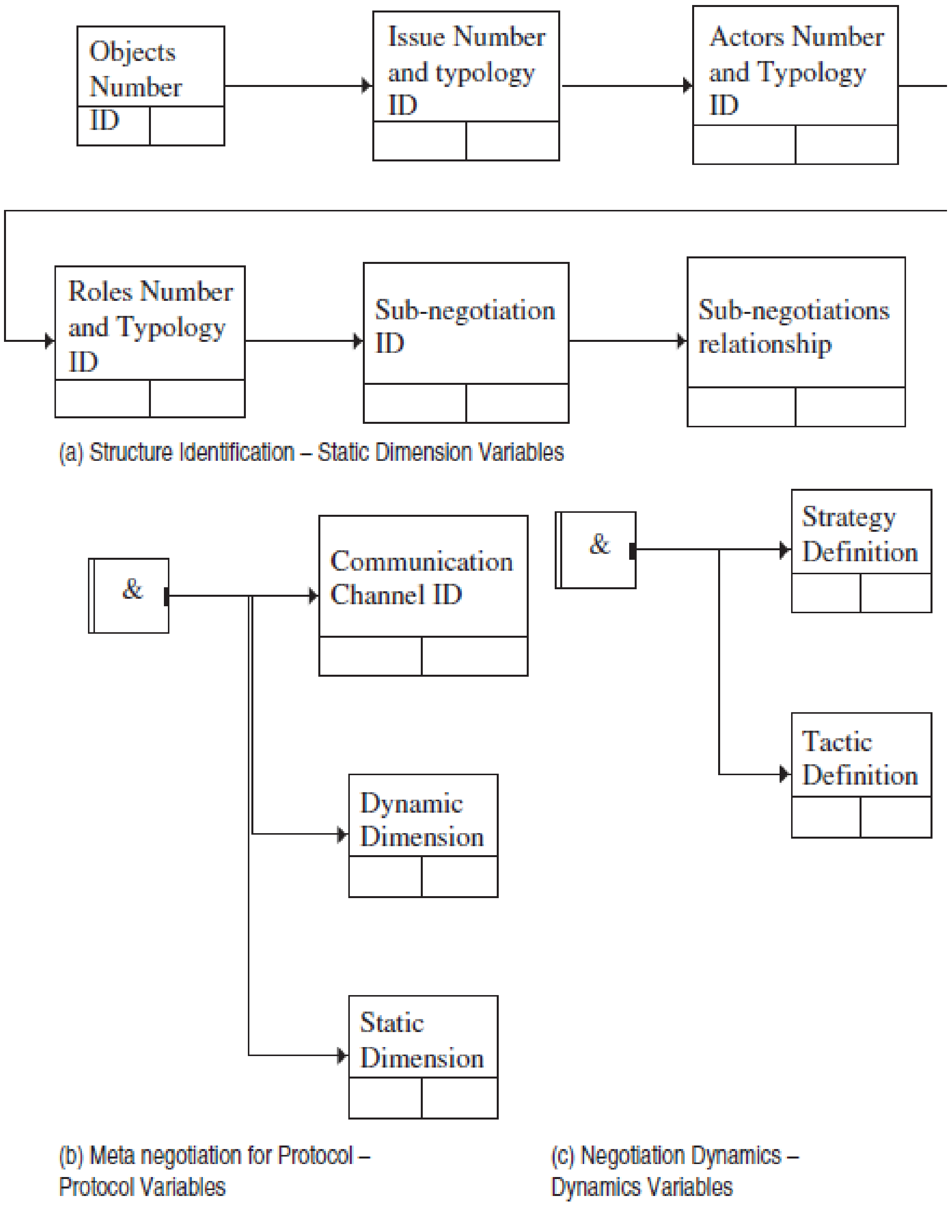


Figure 19. Negotiation design[150]

Moreover, in the negotiation design it would be advisable to determine a certain amount of actions taken into the negotiation, otherwise the negotiation would be endless. Times of sets: T= {0, 1, 2, …, 2n} have to be agreed on in advance and known by all agents.

[150] (Nigro et al., 2006) p.3750

4.4.2 The shape of automatic negotiation

In the first step, a software agent calls for an offer, so that one agent (which one can be defined in the protocol) sends an opening offer, which usually accounts to the utilities defined by the user. In case there are more offers that deliver the same utility levels one offer can be chosen randomly by the agent. In the second step an agent has to evaluate an offer that has been sent from an opponent. Depending on the utility defined by the user's preferences the difference between the aimed utility and an offer can be either positive, same or negative. If this difference is positive this indicates the higher demand for offer. In case of same utility, the agent remains indifferent. While the difference is negative this indicates a concession. In that way all the offers are evaluated depending on negotiating protocol reflecting the user's preferences. More detailed sequence of interaction between the partners has been summarized in the figure 20.[151]

[151] (Filzmoser, 2010)

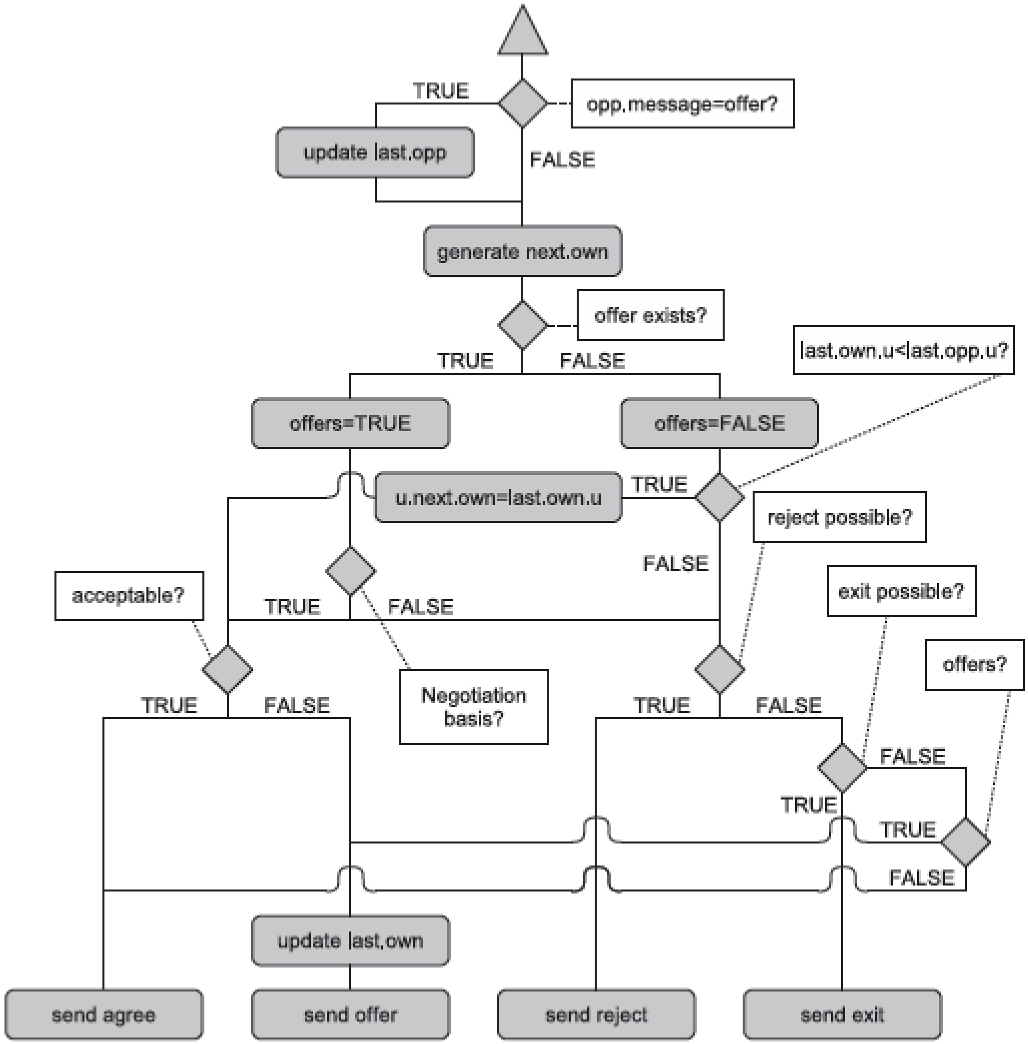


Figure 20. Typical negotiation sequence[152]

One of the classical prototypes of the automatic negotiation over a single issue has been summarized by Chavez and Maes (1996)[153] where autonomous agents negotiate in a marketplace. This idea has been created in order to help vendors and buyers to get the best possible deals. In this paper the authors summarize how a multi-agent system called Kasbah works and supports the interaction between the selling- and buying agent. Here the selling agent is proactively contacting the possible buyers and negotiates with them in order to make a deal. What is special in this study is that the negotiation goes only

[152] (Filzmoser, 2010), p.98

[153] (Chavez & Maes, 1996)

over a single issue, which is the price only. Similarly to other approaches discussed in this dissertation the agents have their reservation prices and the time of negotiation is limited. This prototype aims to sell on higher price than a human would do since the automated negotiation supposed to bring higher expected output.

To start with, the user has to define the utility function of the price over a given negotiation time period. Moreover, before any deal gets finalized the automatic agent requires a final approval from the human operator. The marketplace is a point where both negotiating parties get together and are informed about the existence of the new vendor-, buyer agents. Agents may be eligible only to send offers, ask for price and item. Here, the agents talk to each other at the same time (simultaneous negotiation) by implementing a simple algorithm. Moreover, the negotiation history is able to record the progress of the bargaining process. The agents talk to each other in a very simplified way. When it comes to the role of the selling agents, first, they define the current asking price which is always the highest at the beginning of the negotiation and is getting lower by the time pass, so that is based on concessions. Secondly, they have to make decision to whom to talk to (they can interact with one buying agent once per negotiation circle). They consider all participants than they did not talk to, after they choose one that has never been contacted and consequently further pick the agent with the highest last known offer price. If the price is accepted then the negotiation finishes; if the offer has been rejected there is to ask again for the offering price.[154]

To illustrate what has been elaborated here, a simple example has been developed by Chavez and Maes (1996). Imagine 3 agents: one seller with reservation values [50,100] that is conducting the negotiation and two buyers-first one with reservation values of [50, 85] and second one defining them by [70,110]. The negotiation circle runs as followed:

[154] (Chavez & Maes, 1996)

```
Event: Offered agent 3 100. Rejected.
Event: Asked agent 3 their price. Replied 70.
Event: Agent 2 offered 50. I rejected.
Event: Agent 2 asked my price. I replied 100.
Event: Agent 3 offered 70. I rejected.
Event: Agent 3 asked my price. I replied 100.
Event: Offered agent 3 96. Rejected.
Event: Asked agent 3 their price. Replied 73.
Event: Agent 3 offered 73. I rejected.
Event: Agent 3 asked my price. I replied 96.
Event: Agent 2 offered 53. I rejected.
Event: Agent 2 asked my price. I replied 95.
Event: Agent 3 offered 75. I rejected.
Event: Agent 3 asked my price. I replied 91.
Event: Agent 2 offered 56. I rejected.
Event: Agent 2 asked my price. I replied 91.
Event: Offered agent 3 91. Rejected.
Event: Asked agent 3 their price. Replied 76.
Event: Agent 2 offered 59. I rejected.
Event: Agent 2 asked my price. I replied 87.
Event: Agent 3 offered 78. I rejected.
Event: Agent 3 asked my price. I replied 87.
Event: Offered agent 3 87. Rejected.
Event: Asked agent 3 their price. Replied 78.
Event: Agent 3 offered 81. I rejected.
Event: Agent 3 asked my price. I replied 83.
Event: Offered agent 2 83. Rejected.
Event: Asked agent 2 their price. Replied 62.
Event: Agent 2 offered 62. I rejected.
Event: Agent 2 asked my price. I replied 83.
Event: Offered agent 3 79. Accepted.
```

Figure 21. Example of a negotiation circle by (Chavez & Maes, 1996)

There is to realize that the agent 3 bought the item for the price 79, however a better offer has been available (agents 3 offered 81 and it has been rejected). This happens because agents simply accepted the offers which are meetng their asking prices in the times the first autmatioc negotiation prototypes have been buid.[155]

4.5 Practical examples on negotiation over multiple issues

In order to give some more insight to the topic this section will present some practical examples over the bargaining processes of various actors. In this chapter it will be dis-

[155] (Chavez & Maes, 1996)

cussed a negotiation over multiple issues. First, more simplified example, will be based on discussion over two issues with many resolutions where one has to decide whether to accept the first or the second contract proposed. Second example will summarize a negotiation process of two partners over three issues such as price, time of arrival and payment conditions. Each of the negotiation parties scored the template confidentially and defined their reservation values and best alternatives, nevertheless they negotiate in a full, open and truthful exchange. However, some parties could strategically exploit sensitive information and engage in misinterpretation of their reservation values or other important issues in order to trick the opponent in making concession, here the focus will be based on truth information flow between the partners to maximize their joint profit. Those examples could be used to develop negotiation protocols in the context of Industry 4.0 to maximize the entire supple chain profit of various parties involved in the bargaining processes.

4.5.1 Toy example nr.1: Bilateral model example

First example inspired by the research of (Faratin et al., 1998) is about simple bilateral negotiation over 2 issues: the price and volume of transportation. Negotiating agent, company “a” has to ship between 12 and 24 tons of goods and is searching for an offer from an agent “b” and is able to pay anything between 750 and 1250 monetary units. Let i ϵ [a, b] be negotiation agents and “j” issues to negotiate about. Xj ϵ [min j i, max j i] is the value of the issue “j” acceptable by agent “i”. Each of the agent has a function V_j^i, which gives scores of agent “i” over an issue “j”. Moreover, every issue “j” have an importance (weight) by agent “i”.

The scoring function looks as followed:

$$V^i(x) = \sum_{1 \leq j \leq n} w_j^i V_j^i(x_j)$$

and depicts that the value of an offer “x” from an agent “i” equals the sum over weights of issues multiplied with scores. Simple example will clarfy this uncomplicated function. Reservation values of agent “a” are as followed: [min price of issue; max price of issue]= [750, 1250] which means acceptable price ranges between 750 monetary units and 1250 for a single transport and [min volume of issue, max volume of issue]=

[12, 24] which subjects requested volume of order between 12 and 24 tons to be delivered. Moreover, price is more than twice more imporant than the volume in this negotiation and is represented by additive scoring function: [weight of price for issue, weight of valume of issue]= [0.7, 0.3]

It is assumed that values of price and volume can be defined as following fuctions:

$$V^a_{\text{price}}(x_{\text{price}}) = \frac{x_{\text{price}} - \min^a_{\text{price}}}{\max^a_{\text{price}} - \min^a_{\text{price}}},$$

$$V^a_{\text{volume}}(x_{\text{volume}}) = 1 - \frac{x_{\text{volume}} - \min^a_{\text{volume}}}{\max^a_{\text{volume}} - \min^a_{\text{volume}}}.$$

In this example negotiating agent "b" according to his capacities is able to offer 2 contracts either a combination of [800, 13] or [1000, 18] price and volume respectively. According to the funtion we compute the scoring fuction of the price for the first contact= 800-750/1250-750=50/500=0.1 and volume=1-(13-12/24-12)=0.917 The total value of the first contract will be accoring to our function=0.7*0.1+0.3*0.917=0.3451

Regarding the second contact the the value of the price= 1000-750/1250-750=0.5 and the value of the volume = 1-(18-12/24-12)=0.5. The total value of the second contract is 0.7*0.5+0.3*0.5=0.5, which inducates that compared to the first contact an agent a should rather choose the second one, because it brings him a higher utility.

This simple bilateral model, however can be valid only under some assupmtions (compare (Faratin et al., 1998)), can be used to understand how the weights given to various negotiation participants can be used to decide over the contact that maximizes the utility of one participant. Nevertheless, in the reality scoring function has to be disclosed and it is not possible to optimize an unknown function.[156]

[156] Own modification of example based on (Faratin et al., 1998), p.162-164

4.5.2 Toy example nr.2: More elaborated example over the multi-criteria decision making

The second, more elaborated example inspired by the works of (Raiffa, Richardson, & Metcalfe, 2002)[157] depicts a multi issue negotiation process over three issues adopted to the needs of this research over the possible use of multi-agent systems in Industry 4.0 to resolve the inefficient negotiation outcomes in the supply chain management parties. Here the example has been choosen over the negotition in the the transport disposition problem. Nevertheless, same model would apply for example for any buyer-seller bargaining process. Here, all the possible efficient contacts for both parties (dispatcher and trasnport partner or rather buyer-seller), an efficient Pareto frontier as well as extreme efficient conracts will be identified.

4.5.2.1 Introduction of the problem

In this example there are three issues to negotiate about: price, arrival time and payment conditions. The disptcher's resevation value for possible payment to the transport partner for the delivery issued is between 1000, 1100 and 1200 monetary units, whereas the possible arrival can be fixed (exact day of arrival to the customer) or variable, where the transport partner can deliver the cargo in a range of three days (requested delivery date +/- one tolerance day) due to the long distance shipment environment and certain flexibility from the customer's site. Moreover, the payment to the transport partner can be issued between 20, 30 and 60 days after the delivery has been compleated. The table summarizes the full template problem which is scored by both players.

			Payoffs	
Issue	**Level**		**Dispatcher**	**Transport partner**
Price	1000		60	0
	1100		20	40
	1200		0	70
Arrival	fix		20	0
	variable	+/-1	0	10

[157] Own modification of example based on (Raiffa et al., 2002) p.249-268

	day		
Payment (days)	60	20	0
	30	5	8
	20	0	20

Figure 22. Weights (payoffs) designed by each negotiator

Hence, we have 3 possibilities for price, 2 possibilities for arrival time and 3 different payment conditions which range between 20, 30 and 60 days, so that the number of potencial contracts in this combination equals to 3*2*3=18. The payoffs indicate the weights given by participants, so that for example dispatcher has given 60, 20, 20 points and transport partner 70, 10, 20 for price, arrival and payment respectively. All possible 18 contacts are indicated in the next table. In the columns D until I we see again the scores which were given from the negotiators depending on repeating arrays. Comuns J and K state the accumulated scores for the combination of contracts. Note that, in this and further parts of this work "D" stays for dispatcher and "TP" for tasport partner.

A	B	C	D	E	F	G	H	I	J	K	L
			Price		**Arrival**		**Payment**		**Totals**		**Contract no**
			D	**TP**	**D**	**TP**	**D**	**TP**	**D**	**TP**	
Price	**Arrival**	**Payment**									
1000	fix	60	60	0	20	0	20	0	100	0	1
1000	fix	30	60	0	20	0	5	8	85	8	2
1000	fix	20	60	0	20	0	0	20	80	20	3
1000	variable	60	60	0	0	10	20	0	80	10	4
1000	variable	30	60	0	0	10	5	8	65	18	5
1000	variable	20	60	0	0	10	0	20	60	30	6
1100	fix	60	20	40	20	0	20	0	60	40	7
1100	fix	30	20	40	20	0	5	8	45	48	8
1100	fix	20	20	40	20	0	0	20	40	60	9
1100	variable	60	20	40	0	10	20	0	40	50	10
1100	variable	30	20	40	0	10	5	8	25	58	11

1100	variable	20	20	40	0	10	0	20	20	70	12
1200	fix	60	0	70	20	0	20	0	40	70	13
1200	fix	30	0	70	20	0	5	8	25	78	14
1200	fix	20	0	70	20	0	0	20	20	90	15
1200	variable	60	0	70	0	10	20	0	20	80	16
1200	variable	30	0	70	0	10	5	8	5	88	17
1200	variable	20	0	70	0	10	0	20	0	100	18

Figure 23. List of all possible contracts

The next step is the general evaluation of all contacts. To do this there is to plot all possible contract combinations from the colums J and K (joint evaluations) as followed:

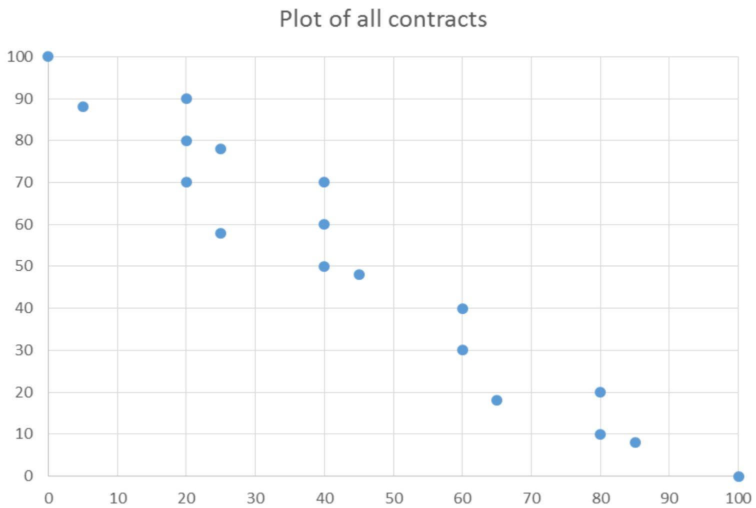


Figure 24. Plot of all contracts

By simple visual inspection we can pick some examples from the plot above which contacts seem to be extreme effcient ones (circled) and would be located on the efficient frontier:

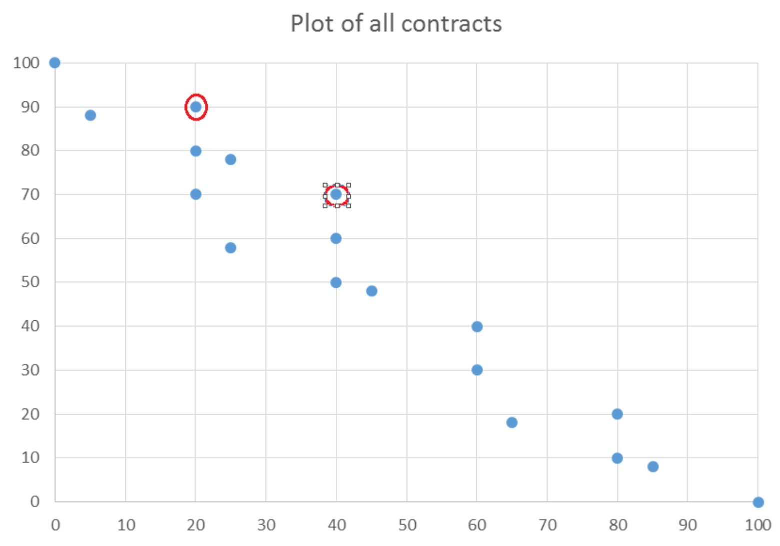


Figure 25. Plot of all contracts with pointing out some selected extreme efficient contracts

Contract with coordinates 20,90 and further 40,70 are examples of the extreme efficient points since are not dominated. To sum up, in that simple way it was shown how to identify some extreme efficient points in order to maximize the outcome of both dispatcher and transport partner by adding their maximized scores.

4.5.2.2 How to find an efficient contract?

In this section it will be described how one can find extreme efficient points without visiual inspection of the plot. Now, the slope will be manipuated by the use of constant "α", where a "ruler" can define a fuction such as maximized ulitility of of dispatcher + α* maximized utility of transport partner (imagine we want to maximize the outcome of the D+α*TP where D is dispatcher's utility and TP-transport partner utility). In the real life negotiation an α would mean the application of some specific negotiating tactics described before (see section 4.3.1.3). Nevertheless, in such a case the problem would arise to very complicated set, so that here the tactic would be represented by one number α.

Formal explanation of concession

To explain how to reach an efficient combination of issues in a contract by both parties by maximizing their joint utilities we would have to go back to the anlytical concession advising technological model described in Vetschera et al (2012)[158]. In this paper the model is a concession based approach between two parties that are bargaining for individual offers. A concession indicates that in every step we obtain less utility (own utility) so that the previous utility in t=0 is bigger than the one in t+1:

$$u_{own}(\mathbf{x}) < u^0_{own}$$

The value creation in bargaining step requires that the common utility (own and of the opponent) will be bigger than the utility before the concession from one participant's side has been done:

$$u_{own}(\mathbf{x}) + u_{opp}(\mathbf{x}) > u^0_{own} + u^0_{opp}$$

Where u^0_{own} and u^0_{opp} are the starting offers. In an a concession based model we are always confronted between the trade-off between the focal negotiatior's utility and the utility of the opponent. Suppose the negotiators want to maximize the level of scores of the first negotiator plus α times the second negotiator's score as indicated before. This concession path includes the values of α which means how much the focal negotiator would give up of his own utility in the negotiation process in order to increase the utility function of the opponent (α is always bigger than zero, otherwise a concession is not made). According to the standard incremental analysis parties should proceed from period t to the next period t+1 only if:[159]

$$u_{own}(\mathbf{x}) + \alpha\ u_{opp}(\mathbf{x}) >= u^0_{own} + \alpha\ u^0_{opp}$$

By transfering this equation to obtain α we get:

$$\alpha = u_{own}(\mathbf{x}) - u^0_{own} / u^0_{opp} - u_{opp}(\mathbf{x})$$

[158] (Vetschera et al., 2012)

[159] (Raiffa et al., 2002)

If we note with index “p” a previous offer and with index “0” the actual offer and assume additionally that we do not have to concede more than requested we can summarize the previous quotation as follwed:

$$\alpha \leq \frac{u_{own}^{0} - u_{own}^{p}}{u_{opp}^{p} - u_{opp}^{0}}$$

The right hand site is called “critial ratio”. If this ratio is bigger than α than we get an improvement (compare table 5).[160]

4.5.2.3 Example of how to find an extreme efficient contract

First, there are to analyze the utility functions of dispatcher and transport partner. When it comes to the price, dispatcher’s aim is to pay as least as possible to the transport partner for his duties, so that the utility is decreasing with the rise of the price. On the contrary, transport partner seeks to maximize his utility in a way he would get the maximal possible price (here 1200 depicts maximal scores).

The two negotiators of the game have their own utility functions, such as:

$$u(\mathbf{x}) = \sum_{k} w_k v_k(x_k)$$

Where “u” is utility of offer “x” and cosists of a sum over all issues “k” (here price, arrival and payment), “w” are the weights assigned to issue “k” and finally “v” is a partial utility fuction.

What is more, for our negotiators marginal utility fuctions would look as follwed:

[160] (Vetschera et al., 2012), (Raiffa et al., 2002) p.258

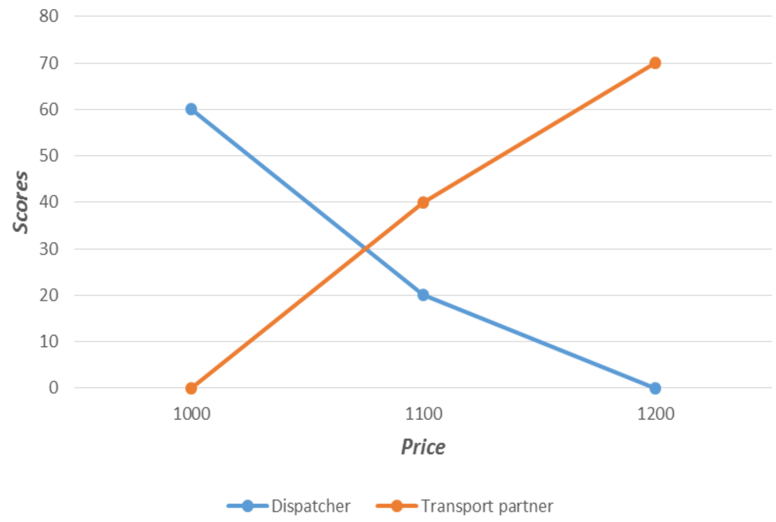


Figure 26. Marginal utility function for attribute price for both negotiators

Concerning the payment, the dispatcher seeks to postpone the payment as much as possible and scores the payment deadline of 60 days with the most points. On the contrary, transport partner wants to get his payment as quick as possible, so his utility function would be decreasing with the rise of the payment deadline (see figure 4).

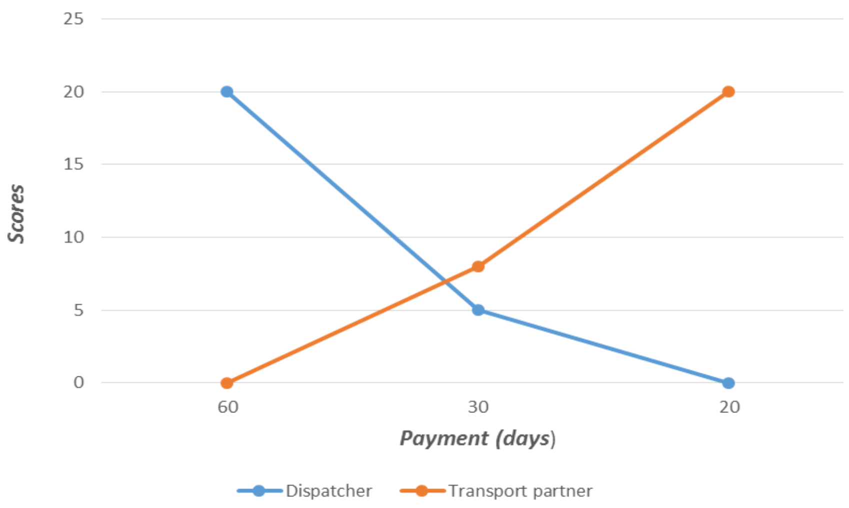


Figure 27. Marginal utility function for attribute payment for both negotiators

Imagine that both parties wants to maximize their common utility and their joint function of: D+TP*α. Here it will be expained how to find efficient contacts depending on various α values, which can be changed by the "ruler"[161]. Constant α can have any non-negative numbers and depending on its size a different contract can be chosen (see

[161] "ruler" can be understood as a methapher for combination of different negotiation tctics

table 3). In the first table α has beeen chosen 0, 9, which creates the biggest value of 1200 for price, fix arrival and 60 payment days.

A	B	C	D	E	F
			Payoffs	**α=**	**0,9**
Issue	**Level**	**Dispatcher**		**D+α*Tp**	**Chosen con-tract**
Price	1000	60	0	60	0
	1100	20	40	56	0
	1200	0	70	63	1
Arrival	fix	20	0	20	1
	variable +/-1 day	0	10	9	0
Payment (days)	60	20	0	20	1
	30	5	8	12,2	0
	20	0	20	18	0

Figure 28. Use of α weights=0, 9 to find an efficient frontier

On the contrary, if the value of α is changed by the “ruler” to 1,83 totally different constellation of the contract would be the most efficient one: price 1200, fix arrival and 20 days of payment (see table 4).

A	B	C	D	E	F
			Payoffs	**α=**	**1,83**
Issue	**Level**	**Dispatcher**	**Transport partner**	**D+α*Tp**	**Chosen con-tract**
Price	1000	60	0	60	0
	1100	20	40	93,2	0
	1200	0	70	128,1	1
Arrival	fix	20	0	20	1
	variable +/-1 day	0	10	18,3	0
Payment (days)	60	20	0	20	0
	30	5	8	19,64	0
	20	0	20	36,6	1

Figure 29. Use of α weights=1, 83 to find an efficient frontier

Since the column F yields the extreme efficient points, we can see that there are exactly the same as choosen by the visual inspection (see figure 23). In the table 3 if we look at the choosen contract price=1200, fix delivery and 60 days for payment. The payoff of the dispatcher consists of 0 points for price, 20 points for arrival and 20 points for payment. The sum over those scores equals to 0+20+20=40. In analogical way transport partner obtains 70 points for price and 0 points for remaining issues. In the figure 23 exactly the point 40,70 has been categorized as extreme efficient one.

By changing α to 1,83 (see table 4) the efficient contract consist of price=1200, fix payment and 20 days for delivery. The dispatcher's scores are equal to 20 (sum of 0 for price, 20 for arrival and 0 for payment) and the ones from transport partner 90 (sum of 70 for price, 0 for arrival and 20 for payment) which yields an efficient point of 20,90 (compare figure 23).

Incremental analysis on how to find all extreme efficient contracts.

In this section the aim is to find all extreme efficient contracts by sorting and dealing from the top. To start with and to understand better this method an example over the utilities in an issue with 5 resolutions with random numbers will be analysed[162] (our previous example of transport partner and dispatcher negotiation consists of not sufficient data -only 3 options for an issue- in order to sketch such a plot of maximization of the function. Nevertheless, it will be described in shortly after this general example).

A	B	C	D	E	F	G	H	I
							Range	
Issue	**Resolution**	**A**	**B**	**Increment to A**	**Decrement to B**	**Critical ratio**	**From**	**To**
XZY	t1	0	30				2	Infinity
	t2	10	25	10	5	2	0,714	2
	t3	15	18	5	7	0,714	0,375	0,714
	t4	18	10	3	8	0,375	0,2	0,375
	t5	20	0	2	10	0,2	0	0,2

[162] (Raiffa et al., 2002) p.259

Figure 30. Maximize value of A + α* value B

Colums E and F depict an increment and decrement of the negotiators as the values change according to the resolution (obtained from the differencies from the columns C and D over the pass of the time). The value in the coulmn G is the critical ratio described above (ratio of the increment to the decrement). In the the next figure (figure 26) those values are plotted showing extreme efficient contracts (columns C and D). In this way we can analyze when is better to move to the second resolution (period). If the constant α is bigger than 2 it is not efficient to move from t to t+1, because the critical ratio have to be bigger (or equal) than the α (see the model in the section 4.5.2.2). Nevertheless, for all values ranging between 2 and infinity the optimality is at the first level. For all α between 2 and 0,714 the second level would be optimal and so one.

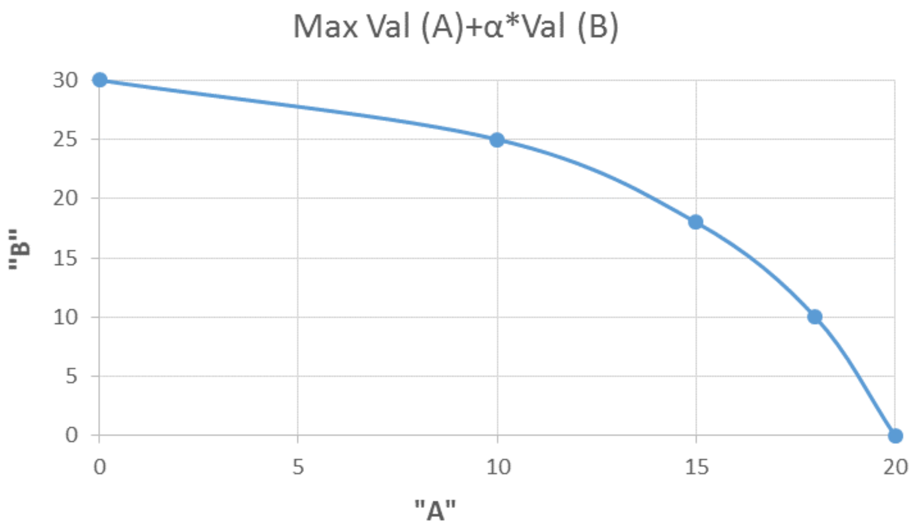


Figure 31. Plot of results of the maximization function

The next table explains the efficient frontier (in a comparable way to the previous example) by passing to the next resolution (form t to t+1) for all three issues: price, arrival and payment for the example of transport negotiation as indicated before.

A	B	C	D	E	F	G
Issue	**Level**	**D**	**TP**	**Increment D**	**Decrement TP**	**Critical ratio**
Price	1200	0	70			
Price	1100	20	40	20	30	0,667

Price	1000	60	0	40	40	1
Arrival	variable	0	10			
Arrival	fix	20	0	20	10	2
Payment	20	0	20			
Payment	30	5	8	5	12	0,417
Payment	60	20	0	15	8	1,875

Figure 32. Transport contraction analysis by the critical ratios

Column E depicts the increments of dispatcher as we proceed with the negotiation down to the next time period (negotiation round). Column F gives the decrement of transport partner, whereas in column G there are to find critical ratios (increment/decrement). Consequently, in order to proceed with the method of finding extreme efficient contracts the table 7 is organized in a way of descending critical ratios, but consists of the same data as table 6.

A	B	C	D	E	F	G	H	I	J	K	L
							Extr.eff.values		**Extr.eff.contracts**		
							D	**TP**	**Price**	**Arrival**	**Payment**
				Incr.	**Decr.**	**Crit.**					
Issue	**Level**	**D**	**TP**	**D**	**TP**	**ratio**	0	100	1200	variable	20
Arrival	fix		0	20	10	2	20	90		fix	
Payment	60	20	0	15	8	1,875	35	82			60
Price	1000	60	0	40	40	1	75	42	1000		
Price	1100	20	40	20	30	0,667	95	12	1100		
Payment	30	5	8	5	12	0,417	100	0			30
Arrival	variable	0	10								
Payment	20	0	20								

Figure 33. Transport contraction analysis by the critical ratios organized by descending α

We start our negotiation by giving "everything" to the transport partner. The contract will be shaped as followed: price=1200, arrival= variable, payment= 20 days. Due to the highest critical ratio at the value of fix delivery (=2), to proceed with this method there is to change the arrival to the fixed one, which implies the increment of dispatcher equaling 20 and decrement of transport partner of 10 (compare table 7). Further, payment is to change from 20 days to 60, which yields an incement of dispatcher (15 points) and decrement of trasnport partner (8 points). As a next step we would change the price from 1200 to 1000 and conequntly to 1100. Last step consists of changing the payment ot 30 days. In coulmn H an I there is to see a change of the values of the negotiatiors' scorings accoring to the variations in the contract paramenters (columns J, K, L).

As next step, we draw a plot that depicts the extreme efficient points. The graph consists of the inputs of column H and I, where the extreme efficient values have been summarized.

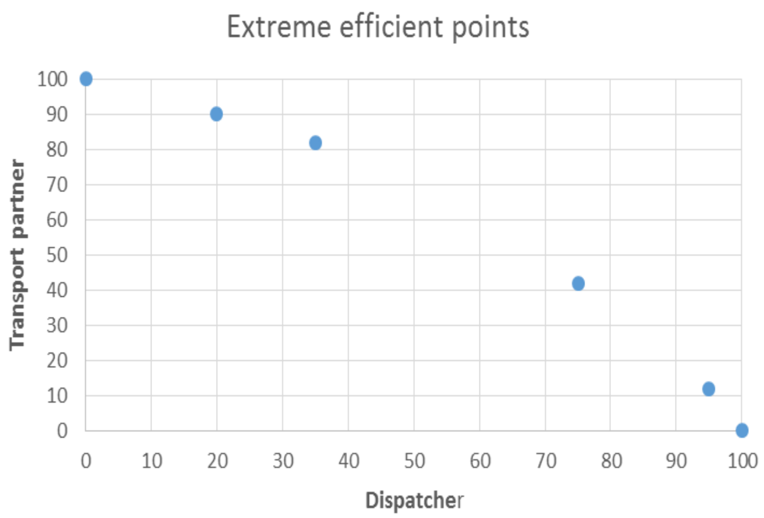


Figure 34. Extreme efficient points

Nevetheless, in this plot we neglect the reservation values the parties may put over the issues to participate in the negotiation process, since for example a point (0,100) will be acceptable and efficient only for the dispatcher and not for the transport partner. To deal with this issue in the next figure (figure 28) there is to assume that the reservation values of dispatcher and transport partner create a common reservation value (acceptable for both parties) where both axis cross. Any contract which will be in the north-west direction of this point would be an efficient one (see efficient frontier on the graph). The point which is depited by “max. feasible value for D/TP” is the point that would maximie a certain participant's utility under the consideration of reservation values.

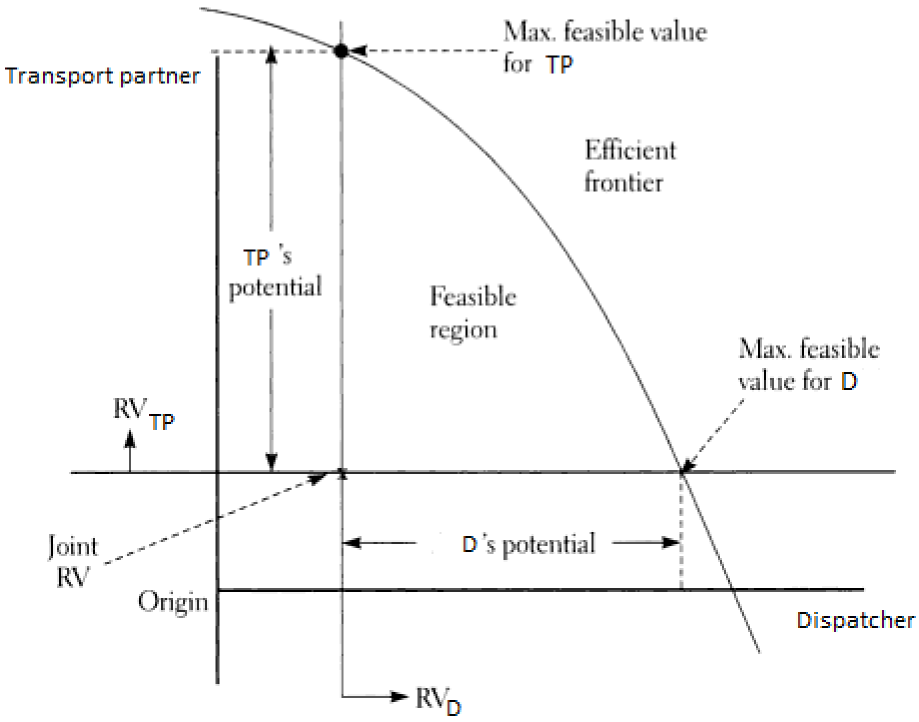


Figure 35. Feasibility and efficiency

Nevertheless, in the reality, without knowing the scoring fuctions and reservation values of the negotiators it is extremely difficult to identify what is feasible for them, so that the figure 28 can only indicate a suggestion. However, in real life parties never reveal their utility functions before the negotiation, such an analysis as conducted here is much more simplified by using a scored template, where parties should jointly maximize their scores.

4.6 Summary of contribution of the section

In this chapter we have seen how it is possible to find efficient contracts (combination over negotiated issues with multiple resolutions) for the partners when the scoring functions over the issues of participants are known. In this framework it was shown how the partners might build their common concession in order to find an maximum possible output for both negotiators while respecting each others reservation values which could be applied in the Industry 4.0 based supply chain management. We also realized that within the same negotiation different α values lead to different processes. This model that suggest size of concessions and lists efficient contracts could provide a tool not only for individual parties, but could be implemented in a multi-agnt decision support system providing an advice concerning the concession steps in order to reach to efficient joint agreement for negotiating agents. Such a system could act as an observer knowing preference values of both parties. In this approach we could see which points in the utility space should be chosen by the negotiators while making the best joint deals.

Moreover, this tool could be applied in the Industry 4.0 field while various agents interact with each other and seek for the best solution while negotiating over various issues. Certainly, a more extended model could involve more issues with more resolutions that would lead to an extreme huge number of possible contracts (alternatives while neogitating) where human decision making would be very limited due to complexity. What limits this model is the use of additive scoring function, which could be explored by employment of non-linear models. This research could also be enriched in application of negotiaton tactic described in this thesis since here, from the simplicity reasons, the negotiatin tactics are summarized only to one parameter, which is α. Nevertheless, it would be very interesting to explore the efficient negotiation outcomes, while some tactis would be applied.

5 Challenges of the Industry 4.0

However, Industry 4.0 implemented by various modern systems seems to be quite promising accompanied by a lot of phenomenal advantages, there is to discuss various challenges resulting from the possible implementation.

First of all, complexity will increase significantly and the managerial efforts will become huge compared to the current situation. Not only lack of standards will cause challenges enlargement, but also exploitation of new markets will increase managerial efforts to handle huge business connections and to satisfy various growing needs of the customers. Certainly, due to mass customization in order to satisfy steadily growing customers' needs logistic effort will increase.

To continue with, many activities would have to be done ad hoc, including re-planning of previously planned activities, which implies more frequent transportation of goods, more dynamics in the planning processes and a rise in costs at the same time.

We could divide challenged resulting from Industry 4.0 implementation into three subcategories, namely: legal-, security- and safety-, and challenges on people.

5.1 Work organisation and design as critical factor of Industry 4.0

Herr Herbert Jodlbauer (FH-OÖ Studienbetriebs GmbH) in his talk within EULOG at the University of Vienna on 17 November 2014 claimed that what is actually new and revolutionary in the Industry 4.0 is not the intelligent digitalization itself (since all the core modules of it are already existing such as MAS or other IT tools), but challenging human conducted coordination issues and management forms.[163] From that reason people will have to evolve a new role within supply chain under the practices of Industry 4.0.

Without a doubt the Industry 4.0 will have a huge influence on the peoples' work. An unending debate concerning the people-machine interaction is a very present field in the

[163] Information obtained from the talk of Herbert Jodlbauer (FH-OÖ Studienbetriebs GmbH) "Impulsvortrag Industrie 4.0" on EULOG 2014 conference on 17.11.2014 at the Univeristy of Vienna

Industry 4.0 discussion. Prof. Reinhart from the Technical University of Munich claims even that in the Industry 4.0 environment the machines will direct the people and not opposite how it is now.[164] Industry 4.0 will change previous forms of factory organization, in particular the current pattern of work organization and personal employment opportunities. Nevertheless, it is widely approved that a perspective of production capacity without humans remains a fiction. However, intelligent systems will be able to substitute the personal, the design of the work organization is claimed to be human-oriented with intelligent products being central giving an active information support from all the system components and parties involved. The product, production and servicing should be integrated in the supply chain processes.[165]

Following the concept of social-technical systems CPS supposed to bring some critical changes in the job-organization for humans. First of all, direct people-machine interaction and resulting from that special job-qualifications, secondly changes in the working structure and job organization in horizontal and hierarchical matters coming along with necessary communication and cooperation of all participants are to mention. Additionally a new job infrastructure with interaction of people with machines will be created.[166] Despite of that, experts still see an implementation of human-oriented job construction in the centre of IOT environment.[167]

Since the speed and innovation are the engines of the business development with the pass of the time, people will have to face the dilemma of being replaced by the machines or change the direction of their skills and acquire new ones. Without a doubt, in nowadays and future business environment intelligent processing will make humans to change their working and educational patterns, but there is not to forget that the devel-

---

[164] (Spath et al., 2014)

[165] http://www.plattform-i40.de/presse/plattform-industrie-40/die-plattform-industrie-40-definiert-industrie-40-und-die accessed on 15 October 2014

[166] (Fue, 2014)

[167] http://www.plattform-i40.de/presse/plattform-industrie-40/die-plattform-industrie-40-definiert-industrie-40-und-die accessed on 2 Dezember 2014

opment and mechanization itself makes possible to concentrate and explore new business fields and create new opportunities as well.

Besides, one of the biggest challenges of CPS in the security context is without a doubt creation of suitable cooperation between the human and systems, because creation of socio-technical approach of the Industry 4.0 is essential and shifts human-technology and human environment.[168] CPS has to answer to the user's expectations and respect them in a way that it learns from his past behaviour. Essential in the systems' understanding of human capabilities is that could help to develop an ergonomic approach that will optimize the overall human-machine interaction. Human-system cooperation requires shared control, transparency, controllability, cooperation as well as conflict-handling (see figure 29).[169] Moreover, RFID or other tagging systems will require integration and relocation of stuff, including additional hiring or maintenance contracts.[170]

[168] (Kagermann et al., 2013a) p.23

[169] (Broy et al., 2012) p.17-18

[170] (Asif & Mandviwalla, 2005) p.17

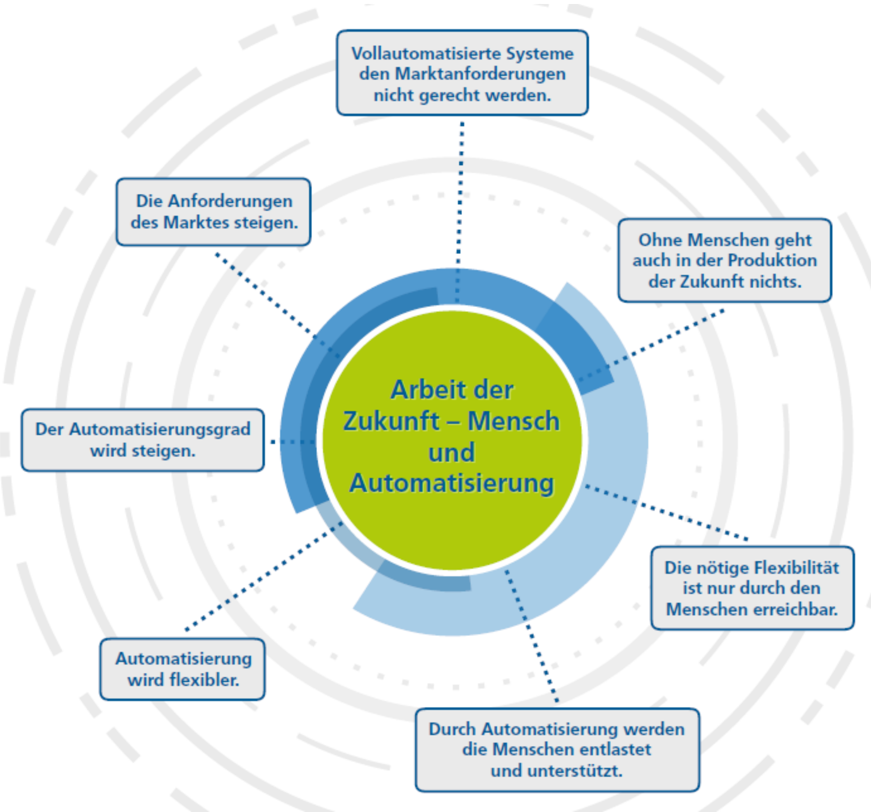


Figure 36. People-machine interaction under the Industry 4.0 implementation[171]

5.2 Security and safety in the digital industrial age

In the big data environment information not only about the products, but also about the people are stored, which gives some ethics concern to discuss about, so that requirements in terms of safety and security of the entire grid have to be considered. The IOT consisting of huge amount of nodes will produce contents, which should be known only by authorized personnel regardless the user's position.[172]

First of all, however CPS supposed to ensure transparency of information, this data will have to be protected, so that CPS will be trustworthy, reliable, available and confidential. CPS are required not only to transfer but also to manage sensitive data. They should

[171] (Spath et al., 2014) p.56

[172] (Atzori, Iera, & Morabito, 2010)p.13

ensure secrecy of information being communicated between various parties whereas the data should not be modified but authentically transferred to the destination.[173]

The IOT infrastructure needs to be resilient to attacks which will target various communication channels. What is more, it needs to be resistant to physical threats, service problems and identity security related problems. It is essential to provide some cryptographic algorithms to secure the flow of information through heterogeneous channels and ensure high throughput of devices and create security protocols at the same time. Another security and safety matter is that users should be granted anonymity in the connected environment and be able to remove their data if desired. Other challenges consist of: identity and authentication of actors and devices being involved in the data management, limited access and its control, protocolling of network security, trust management, governance and fault tolerance mechanisms.[174]

Again, another big- if not the biggest challenge- of CPS in the security context is without a doubt creation of safe suitable cooperation between the human and system, which has been described in the previous chapter.[175]

Another aspect which is necessary to discuss is the privacy needs which corresponds to the use of the CPS. Privacy protection is a significant barrier against the technologies' diffusion ever since, which is well justified.[176] Because the technical architecture of the IOT will certainly impact the security of personal information and a basic human personal rights of privacy policy, the ability of system control is to be considered. Since objects can be tracked and all the information regarding the customer's likes and dislikes or consumer buying behavior[177] will be stored on the database some private actors such as marketing enterprises could overuse the relevant information. However, for example Virtual Private Network (VPN) could limit its border to authorized users, it does not allow dynamic and global exchange of information which third parties beyond the

---

[173] (Broy et al., 2012)

[174] (Weber, 2010) p.2274-2277

[175] (Broy et al., 2012)

[176] (Atzori et al., 2010) p.2802

[177] (Bose & Pal, 2005) p.105

extranet. Other means such as cryptography, peer-to-peer systems, access control, privacy laws have to face a complex problems of data security and user authority in order to guarantee the desired privacy.[178]

5.3 Legal framework

Finally, it is worth debating about the legal issues concerning the data flow. First of all, it is to consider if there is a need of international or just a local law or maybe the current legislation would be sufficient? Those legal issues should be embedded into human right since access control, customer privacy have to be guaranteed. Since self-regulation might not be sufficient new regulatory approaches have to be implemented as well as the scope of the information available by CPS should be limited to necessary data. The respective legislation has to cover some limitations of the data use, new rules on IOT security and establishment of the restriction mechanisms of the IOT.[179]

This legal issues concerning the eminent potential of RFID tagging in the context of IOT is widely known and already recognized by European Commission in 2006 in the workshop “From RFID to the Internet of Things” and in 2009 by providing guidance of 14 lines of actions to the design and operation of the chips application in a manner that would respect the privacy and protect the personal data.[180]

Legal instruments should control which kind of data is allowed to be collected, who is doing that and when and where those data is being distributed. Moreover, storage of the information obtained by CPS should be authorized and kept only until necessarily needed, which should be legally regulated as well.[181]

Finally, a huge issue concerning the standardization is to mention. Without setting legal standards on the communication and authorization of some systems to be used an IOT environment and data exchange remains utopian.

---

[178] (Weber, 2010)

[179] (Weber, 2010)

[180] (Weber, 2009) p.523

[181] (Atzori et al., 2010) p.2802

6 Critics

Hundreds of advantages are steadily being listed from various companies and researchers proclaiming the outstanding intelligence of IOT and trying to sell some revolutionary and superb software and pressure competitors to invest in IT. Nevertheless, there is a lot to discuss about whether the concept could ever become a reality. Certainly, there are various challenges to overcome, but still the whole idea sometimes seems to be unrealistic.

There is to mention a huge cost of investment, which certainly will not be profitable for small and medium enterprises in a full extend since an expected cost of sensors (e.g. RFID) technology implementation can reach even $2 million for a single warehousing system. Such tags are usually not affordable due to the high cost, complexity, maintenance and difficulties in data management and deployment risks.[182] Moreover, complexity of RFID technologies and lack of understanding of it will cause additional problems. Data exchange processes and capturing the relevant ones seem to be a huge obstacle extremely difficult to overcome. Due to lack of experience the deployment and maintenance seem to be demanding. Moreover, volumes of data will be enormous so that current technologies on data storage seem not to be sufficient.

Moreover, a huge problem of data privacy is a serious obstacle to overcome while implementing the concept of Industry 4.0. Multinational companies would be able not only to record information that individuals share (for example in the social media as is happening now), but also track the goods, report customers' preferences, their likes and dislikes. This could be used further in the marketing campaigns and cause even stronger unconscious customer's influence. Since there is no legal framework how to deal with the huge massive data amounts being produced, the ideology of IOT still remains questionable. Furthermore, in the era of cybercrimes being very common, various data could have been stolen and used in an improper way if data security is inefficient.

Additionally, digitalization should be a choice of an enterprise, since it is an irreversible costly investment and integration of all supply chain partners into a common vision of internet of thighs will require that all the partners would have to be interconnected with-

[182] (Jamal et al., 2013) p.79

out an exception. Certainly, leading huge corporations might profit from that, nevertheless in today’s globalized world some smaller actors should also raise their voices.

7 Conclusions

In this paper, it has been explained how the Industry 4.0 might influence certain supply chain management activities with special consideration how helpful the application of multi-agent systems in an automatic negotiation could be. First, the terminology has been deeply analyzed mentioning the most important concepts of cyber physical systems, which interconnected to each other create an environment of Internet of things making possible an intelligent, automatized conduction of activities in the smart factories in the lot size one incorporating individual customers' needs. It has been proved that various supply chain activities could be enhanced via Industry 4.0 implementation by analysis of strategic network design and tactical decisions. Moreover, production, scheduling, distribution, transportation, inventory and many other operational activities could improve from the Industry 4.0 concept implementation in the way that activities would be conducted intelligently in the autonomous production cells without a major human intervention and would find their way along the entire supply chain, passing an atomized inventory systems and replenishing missing products when needed.

In the further part it has been described that multi-agent systems can enhance the communication in the IOT environment. First, the functionality of MAS has been explained, its architecture and motivation. Some special emphasis has been put on the agent automatic negotiation in the buyer- seller environment and particularly transportation negotiation, which has been supported with various examples that could simulate the negotiation course. Moreover, an individual model of agents' interaction in transport negotiation has proved how humans could be released from the information collection and planning activities on behalf of more meaningful tasks. This work showed how various negotiating parties revealing their scoring functions over some particular issues could maximize their common output by identifying the most efficient contracts with the dealing from the top method. This approach could be applied in the development of the negotiating protocol, which is a core of the automatic negotiation.

There is no doubt that Industry 4.0 will not change neither the optimization goal, nor the optimization area, but certainly manner or the means of how a certain optimization goal might be reached, since the process dynamics will be greater. Naming various advantages on Industry 4.0, still some doubts raising from the concept and virtual connection had to be mentioned including safety-, security, legal and challenges of people. However, Industry 4.0 is a great initiative towards the modernization, still some analysis of various challenges of implementability are inevitable, so that the whole concept remains open for further research.

Bibliography

Ashton, K. (2010). That ' Internet of Things ' Thing. *RFiD Journal*.

Asif, Z., & Mandviwalla, M. (2005). INTEGRATING THE SUPPLY CHAIN WITH RFID : A Technical and business analysis. *Communications of the Association for Information Systems*, *15*, 393–427.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, *54*(15), 2787–2805. doi:10.1016/j.comnet.2010.05.010

Bauernhansl, T., Hompel, M., & Vogel-Heuser, B. (2014). *Industrie 4. 0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien und Migration*. Retrieved from http://books.google.com/books?hl=en&lr=&id=QRYpBAAAQBAJ&oi=fnd&pg=PR5&dq=Industrie+4.0+in+Produktion,+Automatisierung+und+Logistik+:+Anwendung,+Technologien,+Migration&ots=WPleaTjkmO&sig=b5y_QafLfegyi7eMITisiTb9qLI

Bose, I., & Pal, R. (2005). Auto-ID: managing anything, anywhere, anytime in the supply chain. *Communications of the ACM*, *48*(8), 100–106. Retrieved from http://dl.acm.org/citation.cfm?id=1076212

Broy, M., Cengarle, M. V., & Geisberger, E. (2012). Cyber-Physical Systems : Imminent Challenges, 1–28.

Chavez, A., & Maes, P. (1996). Kasbah : An Agent Marketplace for Buying and Selling Goods. *AAAI Technical Report*, *SS-96-02*, 75–90. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.21.1129\nhttp://lcm.csa.iisc.ernet.in/ecomm01/paam96.pdf

Chen, Y., Peng, Y., Finin, T., & Labrou, Y. (1999). A negotiation-based multi-agent system for supply chain management. *Working Notes of the …*. Retrieved from http://www.csee.umbc.edu/~finin/papers/papers/agents99-supply-chain.pdf

Chopra, S., & Meindl, P. (2013). *Supply chain management. Strategy, planning & operation*. Retrieved from http://link.springer.com/chapter/10.1007/978-3-8349-9320-5_22

Deshpande, U., Gupte, A., & Basu, A. (2006). Multi-Agent Modeling and Fuzzy Task Assignment for Real-Time Op Norvig, Petereration in a Supply Chain. *Studies in Computational Intelligence*, *28*, 179–202. doi:10.1007/SpringerReference_5244

Dinge, D., & Hille, A. (2013). *smaRTI : Deploying the Internet of Things* (pp. 1–5). doi:10.2195/lj

Faratin, P., Sierra, C., & Jennings, N. R. (1998). Robotics and Autonomous Systems Negotiation decision functions for autonomous agents, *24*, 159–182.

Filzmoser, M. (2010). *Simulation of Automated Negotiation*.

Fue, W. (2014). Industrie 4.0 –, (April), 1–20.

Gronau, N., & Theuer, H. (2011). *Potenziale autonomer Technologien in Produktion und Logistik Potenziale autonomer Technologien in Produktion und Logistik*.

Haasis, H.-D., Wildebrand, H., Plöger, M., & Zimmermann, F. (n.d.). *AMATRAK - TRAFFIC REDUCTION THROUGH INTELLIGENT CONTROL OF FREIGHT SERVICE ON THE BASIS OF AUTONOMOUS MULTI-AGENT* (pp. 1–9).

Ivanov, D., & Sokolov, B. (2012). Article information : *Journal of Manufacturing Technology Management*, *23*(8), 976–997. Retrieved from http://dx.doi.org/10.1108/17410381211276835

Jamal, S. M. K., Omer, A., Abdus, A., & Qureshi, S. (2013). Cloud Computing Solution and Services for RFID Based Supply Chain Management. *Advances in Internet of Things*, *2013*(October), 79–85.

Kagermann, H. (2013). *INDUSTRIE 4.0 – AUF DEM WEG ZUR VIERTEN INDUSTRIELLEN REVOLUTION* (pp. 0–8).

Kagermann, H., Wahlster, W., & Helbig, J. (2013a). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0* (pp. 1–82).

Kagermann, H., Wahlster, W., & Helbig, J. (2013b). *Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. URL: www. bmbf. de/pubRD/ ...* (pp. 1–53). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Umsetzungsempfehlungen+für+das+Zukunftsprojekt+Industrie+4.0#5

Kreinsen, H. H. (2014). *Wandel von Produktionsarbeit – „Industrie 4.0“* (pp. 1–47). Retrieved from http://www.wiso.tu-dortmund.de/wiso/is/de/forschung/soz_arbeitspapiere/Arbeitspapier_Industrie_4_0.pdf

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. doi:10.1007/s12599-014-0334-4

Lin, F., & Lin, S. (2006). Enhancing the Supply Chain Performance by Integrating Simulated and Physical Agents into Organizational Information Systems. *Journal of Artificial Societies and Social Simulation*, *1*(4), 1–65.

Lou, P., Liu, Q., Zhou, Z., & Wang, H. (2011). Agile Supply Chain Management over the Internet of Things. *2011 International Conference on Management and Service Science*, 1–4. doi:10.1109/ICMSS.2011.5998314

Lützen, S. (2010). DVZ. *Amatrak Steuert Die Disposition*.

Moyaux, T., Chaib-draa, B., & Amours, S. D. (2006). Supply Chain Management and Multiagent Systems : An Overview. In *Mulitiagent-Based Supply Chain Management* (Vol. 4, pp. 1–27). Retrieved from http://link.springer.com/chapter/10.1007/978-3-540-33876-5_1

Ng, I., Scharf, K., Pogrebna, G., & Maull, R. (2014). Contextual variety, Internet-of-Things and the choice of tailoring over platform: Mass customisation strategy in supply chain management. *International Journal of Production Economics*, 1–12. doi:10.1016/j.ijpe.2014.09.007

Nigro, G. Lo, Bruccoleri, M., & Perrone, G. (2006). Negotiation in distributed production planning environments. *International Journal of Production Research*, *44*(18-19), 3743–3758. doi:10.1080/00207540600575787

Peng, Z. P. (2014). Analysis and Design of Supply Chain Inventory Management System under Internet of Things Environment. *Advanced Materials Research*, *989-994*, 5520–5523. doi:10.4028/www.scientific.net/AMR.989-994.5520

Raiffa, H., Richardson, J., & Metcalfe, D. (2002). *Negotiation Analysis. The Science and Art of Collaborative Decision Making*.

Spath, D., Ganschar, O., Gerlach, S., Hämmerle, M., Krause, T., & Schlund, S. Produktionsarbeit der Zukunft-Industrie 4.0 (2014). Retrieved from http://www.dkp-niedersachsen.de/produktion/medien/archiv/20131109wesem/Fraunhofer-IAO-Studie_Produktionsarbeit_der_Zukunft-Industrie_4.0.pdf

Stute Logistics (AG & Co.)KG. (2014). Einblicke, Das Journal der STUTE Logisticks (AG & Co.) KG. *1/14*, 1–11.

Stute Verkehrs-GmbH, & Institut für Seeverkehrswirtschaft und Logistik (ISL). (2011). Projekttitel Projektziele. In *Abschlussveranstaltung der Förderinitiative “Intelligent Logistik in Güter- und Wirtschaftsverkehr”* (pp. 1–7).

Tang, J. (2014). A Study of Inventory Management in Supply Chain under the Environment of Internet of Things. *Applied Mechanics and Materials*, *556-562*, 6673–6676. doi:10.4028/www.scientific.net/AMM.556-562.6673

Thaler, M., Czaja, L., & Kai-Ingo, V. (2014). Management integrativer Leistungserstellung. *Betriebswirtschaftliche Schriften*, *168*, 545–567.

Vetschera, R., Filzmoser, M., & Mitterhofer, R. (2012). An Analytical Approach to Offer Generation in Concession-Based Negotiation Processes, 71–99. doi:10.1007/s10726-012-9329-z

Weber, R. H. (2009). Internet of things – Need for a new legal environment? *Computer Law & Security Review*, *25*(6), 522–527. doi:10.1016/j.clsr.2009.09.002

Weber, R. H. (2010). Internet of Things – New security and privacy challenges. *Computer Law & Security Review*, *26*(1), 23–30. doi:10.1016/j.clsr.2009.11.008

Willibald, G., & Hompel, M. (2010). Internet der Dinge in der Intralogistik.

Zhang, F. Z., He, H. X., & Xiao, W. J. (2013). Application Analysis of Internet of Things on the Management of Supply Chain and Intelligent Logistics. *Applied Mechanics and Materials*, *411-414*, 2655–2661. doi:10.4028/www.scientific.net/AMM.411-414.2655

Internet resources:

http://www.plattform-i40.de/presse/plattform-industrie-40/die-plattform-industrie-40-definiert-industrie-40-und-die accessed on 15 October 2014

http://www.bmvit.gv.at/bilder/innovation/fdz/revolution.jpg accessed on 5 December 2014

http://www.dinalog.nl/en/news/new_opportunities_for_logistics_through_cyber_physical_systems/ accessed on 12 October 2014

http://www.roblog.eu/ accessed on 6 of November 2014

http://www.intelligentcontainer.com accessed on 5 of November 2014

http://www.knapp.com/cms/cms.php?pageName=glossary&iD=15&sid=5etpet9giqaepctd18pvjp79m6 accessed on 4 November 2014

http://vimeo.com/79034870 accessed on 5 December 2014

http://www.mckinsey.com/insights/business_technology/the_internet_of_things_and_the_future_of_manufacturing accesses on 18 November 2014

http://blog.bosch-si.com/categories/manufacturing/2013/08/the-internet-of-things-and-the-future-of-manufacturing-pchanging-value-chains/ accesses on 18 November 2014

https://www.bosch-si.com/newsroom/iots/internet-of-things.html accesses on 18 November 2014

http://www.its-owl.de/home/ accessed on 18 November 2014

http://www.dvz.de/themen/themenhefte/transport-logistic/single-view/nachricht/in-spedition-ist-mehr-l accessed on 25 November 2014

http://www.logistik-heute.de/print/10043 accessed on 15 November 2014

https://www.isl.org/en/projects/amatrak accessed on 25 November 2014

http://www.intelligente-logistik.org/index.php?id=amatrak accessed on 26 November 2014 https://www.isl.org/en/projects/amatrak accessed on 26 November 2014

http://www.intelligente-logistik.org/index.php?id=amatrak accessed on 25 November 2014

http://www.logistik-heute.de/print/10043 accessed on 18 November 2014

http://www.logistik-heute.de/print/10043 accesses on 26 November 2014

http://www.isl.org/sites/default/files/projects/amatrak/Flyer_AMATRAK_2011.pdf accessed on 5 December 2014

http://www.isl.org/sites/default/files/projects/amatrak/Flyer_AMATRAK_2011.pdf accessed on 5 December 2014

http://www.logistik-heute.de/print/10043 accessed on 26 November 2014

http://www.bestfact.net/wp-content/uploads/2014/02/Bestfact_Quick-info_efreight_3-100_AMATRAK.pdf accessed 18 November 2014

http://www.intelligente-logistik.org/fileadmin/pdf/Abschlussveranstaltung2011/AMATRAK_AbschlussveranstaltungIL.pdf accessed on 26 November 2014

Eidesstattliche Erklärung

Ich erkläre hiermit an Eides Statt, dass ich die vorliegende Arbeit selbständig und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht. Die Arbeit wurde bisher in gleicher oder ähnlicher Form keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht.

Wien, am 12. 06. 2015

CURRICULUM VITAE

Education

From 03/2013	**University of Vienna,** Austria Master of Science in International Business Administration
10/2007-09/2010	**Freie Universität Berlin,** Germany Bachelor of Science in Business Administration
10/2009–07/2010	**Athens University of Economics and Business,** Greece Student within the Erasmus Exchange programme
08/2009-09/2009	**University of Crete**, Greece Erasmus Intensive Language Course
10/2006-03/2008	**Freie Universität Berlin,** Germany Law studies, elementary degree
09/2000-03/2006	**Bilingual High School**, Szczecin, Poland Bilingual A-Levels

Work experience

02/2011-09/2013	**LKW Walter Internationale Transportorganisation AG**, Wiener Neudorf, Austria Transport Manager
03/2010-08/2010	**CEOWORLD Magazine,** Athens, Greece Country Report Coordinator
03/2010-05/2010	**Polish Embassy in Athens,** Greece Internship

Commitment and scholarships

01/2015	**Academic Council on the United Nations 2015** annual conference, RAUN research presentation
11/2014	**Industry 4.0 conference**, Passau, Germany
05/2014-01/2015	**Regional Academy on the United Nations**
	Research Project for IAEA
10/2013-09/2014	**Performance scholarship of the University of Vienna**
10/2008-04/2009	Funpreneur competition FU-Berlin

Languages

German	Fluent
English	Fluent
Spanish	Fluent
Polish	Native
Greek	Beginner

IT-Skills

MS Office
AS/400
SPSS
SAP-APO
Xpress