FACULTY OF BUSINESS, MANAGEMENT AND ECONOMICS

STEFFEN HOSSFELD

THE IMPACT OF DIGITALIZATION OF DECISION-MAKING PERFORMANCE IN SUPPLY CHAIN MANAGEMENT

DOCTORAL THESIS

Submitted for the Scientific Doctor`s Degree *(Ph.D.)* in Economics and Business

Supervisor: Prof. Dr. Dr. Josef Neuert

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ANNOTATION

Currently digitalization is a game changer for entire industries and society. The technological progress of digitalization is accelerating and will change the entire understanding of doing business from the traditional way as an analogue process to a digital procedure. This new digital setup will create a new business environment. As a result of new working processes, a core task for managers, decision-making, will change completetly. This task will face a tremendous change toward automized and autonomous decision-making of machines by overcoming human decision-making. The question, if digitalization of decision-making will improve the performance of an organization compared to the traditional process of analogue decision-making will be reflected in this dissertation. For a clear focus, the relevance of digitalization on decision-making will be projected in a supply chain environment, to deliver resilient results. The latest trends in supply chain management toward a more digital environment will show the effects of digitalization in manifold examples, e.g. coupling of ERP systems between supply chain partners or the rollout of blockchain systems for autonomous exchange of data or value streams.

The developed research question and the associated hypothesis will be transferred into a research model, which will be tested with adequate research methods. Causual modeling and triangulation of research is used and appropriate for the designed research question, hypothesis and research model. This empirical analysis will show significant results and is able to answer the research question in an appropriate manner. A preliminary interview with senior decision makers exhibits the relevance of the topic and elaborated the importance of it for organizations.

The results show, organizations should use the recently given technologies and tools to implement digital approaches for decision-making in organizations, to increase the quality and the efficiency of the decision process. Finally, the conclusion of this dissertation is a viable verification of the view on digitalization of decision-making and has a positive correlation to the efficiency of decision-making in organizations.

Keywords: Decision-making, digitalization, digital decisions, supply chain management

LIST OF ABBREVIATIONS

3D	3 Dimensional
AI	Artificial Intelligence
B2B	Business-to-Business
BPR	Business Process Reengineering
CEO	Chief Executive Officier
CFO	Chief Financial Officier
CIM	Comupter Integrated Manufacturing
CPS	Cyber Physical Systems
CRM	Customer Relationship Management
EDI	Electronic Data Interface
EDVAC	Electronic Discrete Variable Automatic Computer
e.g.	exempli gratia (for example)
et al.	et alii (and others)
etc.	Et cetera
EUR	EURO (€)
f.	following page
ff.	following pages
GDP	Gross Domestic Product
GPS	Global Positioning System
H	Hypothesis
IIoT	Industrial Internet of Things
IoS	Internet of Service
IoT	Internet of Things
IT	Information Technology

IMF	International Monetary Funds
ISO	International Organisation for Standardization
JIT	Just In Time
KPI	Key Performance Indicators
MIT	Massachusetts Institute of Technoloy
MRP	Material Resource Planning
OEE	Overall Equipment Effectiveness
P.	page
PERT	Program Evaluation and Review Technique
Pp.	Pages
PLS	Partial Least Squares
QR	Quick Response (Code)
RFID	Radio Frequency Identification
RPA	Robot Process Automation
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reverence (Model)
SEM	Structural Equation Model
SEU	Subjective Expected Utility Theory
SQL	Structured Query Language
TQM	Total Quality Management
USD	US-Dollar
WEF	Word Economic Forum
WIP	Work In Progress
WTO	World Trade Organization

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INTRODUCTION

Nowadays, digitalization is one of all mega trends, with an enormous development over the recent years. Researchers in scholar and practice evolved the development of this discipline, with effects in manifold areas of life. According to several authors, digitalization is a wide field of research. Not only research, scholar and business life are affected, almost all circumstances of human activities will be moved from an analogue to a digital structure. From a global perspective automation and digitalization will deploy its full effect in international and global organizations. This change in the attitude to work will change organizations and working processes, hence new challenges will appear for work force, management and collaboration. In this dissertation, a typical management task - decision-making - will be item of examination. Decision-making and decision-making theory is a broad field in science and research, not only for economists. Many other disciplines contributed to this scientific area and created a broader view on decision-making with pioneering ideas and theories. Focusing on decision-making, early ideas emerged up to sophisticated theories over various disciplines. Nowadays, in the age of digitalization, decision-making in organizations, will be transferred to digital infrastructure and devices. The scope of decision-making will change and the associated process of decision-making either. Depending on respective organizations and the own structure of industry scope, customers, suppliers and internal resources, a digital setup for each individual organization will deliver the goal of being more efficient in decision-making. Huge organizations may be in an advantageous position, because of their size to manage these transformation projects and due to economies of scale. An important function in business is strongly affected by digitalization, supply chain management, with huge potential to increase efficiency and performance. Supply chain management will be in the scope of this dissertation and digitalization effects will be explained based on this organizational function.

Actuality of the Topic

Digitalization is a new paradigm. „Data-driven transformation is becoming a question of life or death in most industries“[1], which means the competitive landscape will move in a new structure. Businesses need an answer to new challenges and consumers experience the trend with „smart, connected products having three core elements: physical components, smart components, and connectivity components.“[2]

In the 2016 “Global Perspectives Barometer”, about 800 “Leaders of Tomorrow” cited “hierarchy that slows down decision-making” as the second most substantial risk for established companies in today’s fast-paced markets.“[3] This means, digitalization will tremendously affect decision-making and change the process, including results. Early economists were focusing on utility maximization, from Adam Smith to von Neumann and Morgenstern, and postulated a rational approach to reach efficiency in an organization. Later, these ideas were blurred by organizational or psychological research, e.g. from

[1] Gouvrevitch A. & Faeste L. & Baltassis E. & Marx J., 2017. Data-Driven Transformation – Accelerate at Scale Now. BCG Perspectives. 05/2017. P. 1. The Boston Consulting Group
[2] Porter M.E. & Heppelmann J. E. How Smart, Connected Products Are Transforming Competition. 11-2014. Harvard Business Review. P. 5. Reprint R1411C. HBR.ORG
[3] Neus A. & Buder F. & Galdino F. Are You Too Successful to Digitalize? How to Fight Innovation Blindness. Innovation Blindness / Vol. 9, No. 1, 2017. De Gruyter Open doi 10.1515 / gfkmir-2017-0005. P. 35

Simon with his contribution to „bounded rationality“ and the view on limited cognitive intelligence or an emotional view from Kahneman and Tversky, with a clear scope on behavioral aspects of decision-making. These outcomes of the latest researches established different pictures on decision-making, not necessarily utility maximization. Today, latest technology with huge processing power is able to design decision models and operate them to reach utility maximization. Depending on the automation degree of decision-making, machines are able to decide instead of human beings, related with higher efficiency and accuracy. First time in history, the ideas of early economists are becoming real by pure usage of digital power and algorithmic models for decision-making.

Today's view on digitalization is relevant, because it will change economical structures. Kondratieff's waves show the evidence, in the last years the next wave has already started, about the year 2009, with the financial crisis.[4] Consequently, a new type of decision-making is necessary and the analysis of the current status of decision-making is a starting point to discuss the new way of making decisions.

Supply chain management is meanwhile a strategic function in organizations and affected by digitalization. Digitalization of supply chain management will deliver efficiency gains with new ways of collaboration and digital tools. „Digital transformation requires a digital mindset and new approaches to dealing with both, decision risk and decision speed.“[5]

Aim of Dissertation

The aim of this dissertation is to develop a new model, which exhibits the performance of digitalization of decision-making in supply chain management in comparison to an analogue decision, measured by the degree of the digital setup for decisions.

1. To execute secondary research on the status quo of the academic understanding for decision-making and digitalization in supply chain management.

2. To design a new model for analysis of digitalization effects of decision-making performance in supply chain management.

3. To execute various empirical methods to analyze the implications of the new model

4. To analyze the quantitative research results using various methods as descriptive statistics, regression analysis, correlation, variance analysis and structural equation model analysis. These results will evaluate the impact of digitalization of decision-making performance in supply chain management.

5. To analyze the qualitative research results and key remarks of participants.

6. To reflect and triangulate the research results from qualitative and quantitative research.

[4] Wilenius M., 2014. Leadership in the sixth wave - excursions into the new paradigm of the Kondratieff cycle 2010 - 2050. Eur J Futures Res. Springerlink.com

[5] Neus A. & Buder F. & Galdino F. Are You Too Successful to Digitalize? How to Fight Innovation Blindness. Innovation Blindness / Vol. 9, No. 1, 2017. De Gruyter Open doi 10.1515 / gfkmir-2017-0005. P. 31

7. Finally, to develop recommendations based on research results.

Main Hypothesis & Thesis to Defend

Taking digitalization of decision-making into scientific context, the research question is asking for a relationship between an intelligent digital setup for decision-making and the efficiency of the decision. The intelligent digital setup means a well customized system for an organization which enables an efficient process, for this particular organization. The intelligent setup has to respect the structure of an organization, like industry affiliation, size, spread or customer structure. A digital setup means all organizational procedures are transferred into a digital context, either fully digital or executed by a cyber physical system. The quality of decisions has to be taken into context to the origin of the decision, in an analogue environment. The research question will focus on the key aspect of the dissertation:

Is there a relationship between an intelligent digital setup for decision making and the efficiency of the decision?

This research question leads to the main hypothesis of the dissertation and thesis to defend, which will analyze the dependency of efficiency of decision-making and the digital setup for decision-making. Based on the research question, if there is a relationship between an intelligent digital setup for decision-making and the quality of this decision, the main hypothesis of this dissertation is defined as:

H0: The efficiency of decisions depends on the degree of an intelligent digital setup for decision-making.

To justify (or falsify) the main hypothesis, several sub hypotheses are considered:

H1: The more intelligent the digital setup for decision-making of organizations, the better the efficiency of the decision.

H2: The more manual (human) procedures for decision-making of organizations, the worse is the efficiency of the decision.

Methods and Sources Used

The literature review focused on qualified and peer-reviewed sources with a priority on research articles in academic journals and books. Caused by the latest developments in the area of digitalization, a broader scope of articles and books is relevant for a full depth analysis. Private organizations are focused on research of digitalization, though secondary research sources for market data or general statistics, including official government, public and private organizations had been also relevant. Primary research is based on the results of a “structured professionals interview” and a survey rollout out as an “online questionnaire”. New statistical data from the empirical analysis of the research are processed for statistical analysis and evaluated in research findings. A **Structured Professionals Interview** was executed to rank the importance of the topic digitalization in organizations. The author of the dissertation performed 21 interviews. These interviewees are managers and senior executives and therefore professional decision makers in their organization or are occupied in scholar with an understanding of

decision-making. An important part was the combination of questions, between structured and open questions to collect quantitative data and expressed opinions. A **Survey as an Online Questionnaire** was the tool to proof the theoretical model of the dissertation. A survey as an appropriate technique was developed and rolled out as an online questionnaire. The response of 104 qualified answers was the result. This data set was the appropriate level to run statistical analysis. Focus area was the decision aspect in a supply chain management, based on the SCOR model.

Novelty

1. The novelty of this dissertation is a new research model, which is able to exhibit the performance of digitalization of decision-making in supply chain management, which allows to measure the increase of efficiency of organizations by digitalization of decision-making. Developed from a generic model to a dependency model for a supply chain decision.
2. A new term is introduced as “intelligent digital setup”, into the scientific community.
3. New measurement items for performance measurement of digitalization of decision-making in supply chain management are exhibited in this dissertation, to present the difference between a traditional decision and a digitalized decision, based on the dependency model for a supply chain decision.
4. A further novelty is the categorization of influencing factors for digitalization of decision-making, exhibited in theory and assessed in the empirical part of the dissertation.
5. Finally, the dissertation will give empirical evidence that digitalization of decision-making will increase the performance of decision-making.

Research Object and Research Subject

The research object for the dissertation is defined on decision-making, because this is the instrument to analyze the subject of digitalization. Hence the research subject is digitalization and its impact on organizations implies a huge field of research. It seems to be supportive, to focus on the topic with research question and hypothesis. Besides this structure, to narrow the scope, the function of supply chain management is a frame for this dissertation.

Limitations of Research

The general view on the research object decision-making as an instrument to analyze the research subject digitalization and its impact on organizations implies a huge field of research. To focus this dissertation, it is helpful, to narrow the topic with a scope on supply chain management.

The wide area of decision-making in scientific research contributed massive knowledge in different disciplines, like economy, mathematics, statistics, social, psychology and computer science. The scope of this dissertation is purely focused on the decision process, moved from analogue to digital procedures. A similar procedure is given with organizational theory, which is solely used for the scope of decision-making in organizations. Organizations itself are seen as existing environmental objects, with a reference to the decision-making process. Not all possible digital decisions had been analyzed, based

with the generic model. The opportunity for further analysis of decisions is given, for researches to analyze more business cases in the field of decision-making.

For the theoretical part of the dissertation, the usage of research papers and studies are not comprehensive, because of novelty and latest developments in digitalization. Furthermore, research of this topic is done in private organizations, because of the possibility to create a profitable business model with these results. To increase the quality of the dissertation the author decided, to use business researches to exhibit latest results of the topic of digitalization and to discuss all relevant sources.

The geographical center of the empirical part of the dissertation was mainly located in Germany and European countries, with the focus on German speaking interview partners, though the results are limited to a regional scope. The main idea was, to roll out the interview (partly in English) and the questionnaire in German, to raise the quality of discussions, answers and remarks, and to avoid a language barrier.

A huge area of interest is, based on a new approach of making decisions, the future structure of workers and departments in organizations. A lot of decision makers are today relevant to steer the organization, but in the future a bundle of decisions will be executed autonomously by machines. Therefore, the utilization of these jobs is a vital topic for organizations and economies. The question, how to distribute labor and develop a workforce for peaceful cohabitation without conflicts, has to be solved on a macro-economic level. A research of Boston consulting group predicts that up to 25% of today's jobs will be replaced by software or robots. In addition, a survey of Oxford university has suggested that 35% of existing jobs in the UK are at risk for automation within the next 20 years. As example, this trend is already reality today, because Foxconn, a manufacturer of electronic devices, is planning a force of robots to replace 30% of its human colleagues within the next five years.[6] This topic will not be discussed in this dissertation, because these are effects of digitalization of decision-making in a wider view.

Supply Chain Management is only one function in an organization, and the topic itself would have the opportunity to discuss and analyze other functions in an organization either. For the supply chain management part, the view was purely on the sourcing aspect, to get a single task of the SCOR model, with a deep and detailed understanding and analysis. Supply chain management digitalization is a wide area for researchers, therefore other business cases are also relevant for improved decision-making by digitalization, but not part of this dissertation.

Further implications, as legislation of digitalization, are not in scope of this dissertation. The European Union is currently setting up a proposal for the handling of robots and artificial intelligence in general. This major aspect of digitalization will not be covered in this dissertation, but has an influence on digitalization of decision-making, because the question, what a machine is allowed to decide, has an important influence on business, society and research.

[6] Wakefield J., 2015. Intelligent Machines: The jobs robots will steal first. http://www.bbc.com/news/technology-33327659. Accessed: 28.02.2018

Approbation of Research Results

Conferences

1. Hoßfeld, S.: Optimization on Decision-Making Driven by Digitalization. International Academic Conference „New Challenges of Economic and Business Development“, Riga, Latvia. 12. – 14. May 2016
2. Hoßfeld, S.: Digitalization Effects on Organizations. International Academic Conference of Management, Economics and Marketing. Budapest, Hungary. 08. – 09. July 2016
3. Hoßfeld, S.: Influencing Factors of Digitalization on Decision-Making. International Academic Conference of Management, Economics and Marketing. Vienna, Austria. 25. – 26. November 2016
4. Hoßfeld, S.: Relevance of Digitalization on Decision-Making. International Masaryk Conference for Ph.D. Students and Young Researchers. Online. 12. – 16. December 2016
5. Hoßfeld, S.: The Advantage of Digital Decision-Making Explained by an Investment Decision Case. 75th Annual Scientific Conference of University of Latvia „Impact of Globalization to National Economies and Business. Riga, Latvia. 26. January 2017
6. Hoßfeld, S.: The Advantage of Digital Decision-Making for Strategic Decisions – Proofed by a Supply Chain Case. International Academic Conference „New Challenges of Economic and Business Development“, Riga, Latvia. 18. – 20. May 2017
7. Hoßfeld, S.: Digital Strategic Decision-Making – Analyzing a Questionnaire of Professionals. International Academic Conference on Management, Economics and Marketing. Vienna, Austria. 24. – 25. November 2017
8. Hoßfeld, S.: Optimizing Strategic Decision-Making by Digitalization – a Laboratory Experiment. International Masaryk Conference for Ph.D. Students and Young Researchers. Online. 18. – 20. December 2017
9. Hoßfeld, S.: The Impact of Digitalization on Decision-Making – A Structured Professionals Interview. International Academic Conference „New Challenges of Economic and Business Development“, Riga, Latvia. 10. – 12. May 2018
10. Hoßfeld, S.: Digitalization of Decision Making in Supply Chain Management. CER 2021 – Comparative European Research. Online. 29. – 31. March 2021

Publications

1. Hoßfeld, S.: Optimization on Decision-Making Driven by Digitalization. In: Proceedings of International Academic Conference „New Challenges of Economic and Business Development“, Riga, Latvia. 12. – 14. May 2016, ISBN 978-9934-18-140-5, pp. 279 - 288
2. Hoßfeld, S.: Digitalization Effects on Organizations. In: Proceedings of International Academic Conference of Management, Economics and Marketing (IAC-MEM 2016). Budapest, Hungary. 08. – 09. July 2016, ISBN 978-80-906231-3-5, pp. 163-176
3. Hoßfeld, S.: Influencing Factors of Digitalization on Decision-Making. In: Proceedings of International Academic Conference of Management, Economics and Marketing (IAC-MEBM 2016).Vienna, Austria. 25. – 26. November 2016, ISBN 978-80-906231-6-3, pp. 6 - 17

4. Hoßfeld, S.: Relevance of Digitalization on Decision-Making. International Masaryk Conference for Ph.D. Students and Young Researchers. Online. 18. – 20. December 2017, ISBN 978-80-87952-22-1, Vol. 8, pp. 98-107
5. Hoßfeld, S.: Optimization on Decision-Making Driven by Digitalization. Economics World, Volume 5, Number 2, Mar.-Apr. 2017 (Serial Number 21), DOI: 10.17265/2328-7144/2017.02.001, pp. 120-127
6. Hoßfeld, S.: The Advantage of Digital Decision-Making for Strategic Decisions – Proofed by a Supply Chain Case. In: Proceedings of International Academic Conference „New Challenges of Economic and Business Development", Riga, Latvia. 18. – 20. May 2017, ISBN 978-9934-18-242-6, pp. 202-212
7. Hoßfeld, S.: The Advantage of Digital Decision-Making for Strategic Decisions – Proofed by a Supply Chain Case. In: International Journal of Management Science and Business Administration, Volume 3, Issue 5, July 2017, Pp. 7-20. DOI: 10.18775/ijmsba.1849-5664-5419.2014.35.1001.
8. Hoßfeld, S.: Digital Strategic Decision-Making – Analyzing a Questionnaire of Professionals. In: Proceedings of International Academic Conference on Management, Economics and Marketing (IAC-MEBM 2017).Vienna, Austria. 24. – 25. November 2017, ISBN 879-80-88203-04-9, pp. 219
9. Hoßfeld, S.: Optimizing Strategic Decision-Making by Digitalization – a Laboratory Experiment. In: Proceedings of International Masaryk Conference for Ph.D. Students and Young Researchers. Online. 18. – 20. December 2017, ISBN 978-80-87952-22-1, pp. 98-107
10. Hoßfeld, S.: The Competitive Advantage of Digital Decision-Making for Strategic Decisions – in Scope of the Supply Chain. In: Management Studies, Mar.-Apr. 2018, Vol. 6, No. 2, doi: 10.17265/2328-2185/2018.02.006, pp. 127-138
11. Hoßfeld, S.: The Impact of Digitalization on Decision-Making – A Structured Professionals Interview. In: Proceedings of International Academic Conference „New Challenges of Economic and Business Development", Riga, Latvia. 10. – 12. May 2018, ISBN 978-9934-18-344-7, pp. 246
12. Hoßfeld, S.: Digitalization of Decision Making in Supply Chain Management. In: Proceedings of CER 2021 – Comparative European Research. Online. 29. – 31. March 2021 ISBN, 978-1-9993071-7-2, pp. 17-20

Structure of Dissertation

The dissertation is structured in three main chapters. The **first chapter** represents a literature review of decision-making theory, digitalization theory and supply chain management theory. Decision-making is a traditional theory of early economists and the ideas are reaching back for centuries. The interdisciplinary development of decision-making found access to manifold disciplines in science. The author explains two views on **decision-making**. A **rational** one, based on pure calculations and statistics on the one hand and a behavioral one, with an **emotional** aspect on the other hand. Bringing **digitalization** into context of this dissertation, the practical and theoretical content is developing very fast. The digital representations are binary-coded files with a sequence of bits and bytes, but in a more prevailing interpretation of digitalization, the view is more focused on automation, autonomous or cyber

physical systems.[7] Important to analyze is the logic of digitalization and to realize the 4 areas of transformation, **smart data (big data), automation, integration and digital customer access**.[8] Adding a fifth transformation area **- new business models** – will complete the view on the topic. **Supply chain management** will contribute theoretical foundation and focus the topic of the dissertation to a certain extent, because supply chain management is a relevant function in organizations which will exhibit the fact of digitalization of decision-making.

The **second chapter** puts **research** context to the topic and analyzes previous experience in the field of **digitalization of decision-making in supply chain management**. In general, the goal for efficiency increase is in scope of every organization. Decision-making is converted over time to an automated or autonomous process, which will be displayed by a holistic model of Gartner Hype Cycle and a more applied model of digitalization of organizations by Fraunhofer Institut. More detail will be explained by supply chain research papers in the context of digitalization of the supply chain function.

The **third chapter** will explain the model development with the related research question and main hypothesis. The model will be defined with underlying dependent and independent variables for model testing. The empirical design was executed by a structured professionals interview to analyze the relevance of the topic itself and the second empirical design is based on a supply chain decision case as a questionnaire. Both research findings, of the interview and the questionnaire, are analyzed in the last part of chapter three.

Finally, in the part Conclusions & Suggestions, the results of chapter three will be evaluated and brought into context to the research question and hypothesis. Continuing suggestions should motivate practitioners and researchers for further studies.

Words of Gratitude

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[7] Hess T. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/lexikon/technologien-methoden/Informatik--Grundlagen/digitalisierung. Accessed: 03.01.2018

[8] BDI Research. 2015. Die digitale Transformation der Industrie; BDI – Bundesverband der deutschen Industrie. Accessed: 04.06.2017

1. THEORETICAL FOUNDATION OF DECISION-MAKING, DIGITALIZATION & SUPPLY CHAIN MANAGEMENT

Decision-making is a wide field in science and practice, with a long tradition and distinguished views on decision theory. „The basic idea that humans make choices and that these choices are informed by assessing alternatives in terms of their consequences underlies much of contemporary social science, not to mention common sense.“[9] The first idea of decision theory reaches back over centuries. Rational models were discussed from the neoclassical economists (e.g. Adam Smith or Max Weber) with an idea on rational behavior of agents which maximize utility – as homo oeconomicus. The theories of Pascal or de Fermat shows a calculation of probabilities and Bernoulli laid the foundation of risk science by examining random events. Further developed by von Neumann and Morgenstern economic behavior in a mathematical model, decision-making follows utility maximization. One of the most popular is still the theory of games and economic behavior[10]. This theory of von Neumann and Morgenstern explains a rational behavior of market participants (either consumers or entrepreneurs). Consumers aspire maximum utility or satisfaction and entrepreneurs aspire maximum profits. Today the mathematical models of rational theories are further developed on the ideas of von Neumann and Morgenstern's theory. Over the last decades a more interdisciplinary science developed (economics, psychology, sociology, philosophy, mathematics, computer science and statistics), with different approaches[11]. The opposite of the rational view, is a behavioral view on decision-making. In the late 1940ies Herbert A. Simon discussed the theory of bounded rationality and laid an essential foundation for a development of decision-making theory. This theory is based on a certain influence of human attitudes and not on pure rational decisions. A deeper view in psychology shows that theories on behavioral economy are currently popular, because human behavior is an important part of organizational actions. In the 70ies of the last century, David Kahneman and Amos Tversky developed amongst others an idea, the prospect theory. The idea of the prospect theory is a more human view on decision-making. The theory of Kahneman and Tversky demonstrates that market participants do not act as rational as assumed, i.e. discussed by early economists.

"Digitalization refers to the practice of taking processes, content or objects that used to be primarily (or entirely) physical or analogue and transforming them to be primarily (or entirely) digital. The effect of digitizing processes, aside from potential efficiency gains, is to make processes more tailorable and malleable".[12] Not only based on data, moreover targeted on markets, organizations and processes, digitalization will deploy its full value to businesses and industries. The new era of digitalization has started already and exhibits a first view on a new business world with a completely change in division of work. In the last century a "computer" was an employee calculating tables the whole day. Currently the speed of development is increasing, either the trend of "Industry 4.0" with full automation of the

[9] March J. & Simon H.A., 1997. Organizations. Cambrigde and Oxford: Blackwell. P. 7
[10] Neumann von, J. & Morgenstern O., 2007. Theory of Games and Economic Behavior – Sixtieth Anniversary Edition. Princeton: University Press
[11] Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review
[12] Fichman R. & Dos Santos B. & Zheng Z., 06/2014. Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. MIS Quarterly Vol. 38 No. 2, pp. 329-353

production flow[13] or "artificial intelligence" that robots tend to make autonomous decisions and developed self-awareness and self-maintenance.[14] Robots and machines are moving into our work environment and will replace human work and human decisions. Referring to the effects of digitalization, this trend will change the attitude of making business and making decisions. Flexibility and transformability are key attitudes of successful organizations in the future and drive them on the road of digitalization.[15] Digitalization will have an effect on customer structure and behavior, increase the efficiency of operations including the supply chain and at the end may change the entire business model.

1.1. Theoretical Analysis of Decision-Making

1.1.1. History of Decision-Making

Reflecting the first ideas of decision-making, theories are reaching back to the beginning of economic ideas. In "The Wealth of Nations, published in 1776, Adam Smith argued that economic behavior was motivated by self-interest"[16], with similar ideas as John Stuart Mill[17]. The agent is known as economic man or homo oeconomicus and attempts to maximize utility (consumer) or profit (producer). The first general view on rational behavior of agents which maximize their utility, was developed over time to a scientific theory in economics. A more mathematical approach of two French mathematicians, Blaise Pascal and Pierre de Fermat showed a calculation of probabilities of a simple game.[18] Later, a combination of this mathematical approach and economic view was an important part of decision theory. Daniel Bernoulli laid the foundation of risk science by examining random events with his scientific work. His intent was to create mathematical tools that would allow anyone to estimate prospects from any risky transaction in scope of specific financial situations. In other words, given the chance of a particular outcome, of how much is an agent willing to bet.[19] By and by, mathematical tools found the way into the increasing field of decision theory. Bayes ideas and examinations of probabilities and Gaussian distribution or square method, became important for decision theory.

In 1921 Frank Knight introduced a risk driven approach in economic analysis. He distinguished between risk, when the probability of an outcome is possible to calculate (knowable), and uncertainty, when the probability of an outcome is not possible to determine (unknowable). This usage of calculations rendered

[13] Zelinski P., 02/2016. Where 4.0 Might Go. http://www.mmsonline.com. Accessed: 10.04.2016
[14] Lee J. & Kao H. & Yang S., 2014. Service innovation and smart analytics for Industry 4.0 and big data Environment. Science direct, Procedia CIRP 16 (2014) 3 – 8: Elsevier
[15] Bauer W. & Hämmerle M. & Schlund S. & Vocke C., 2015. Transforming to a hyper-connected society and economy – towards an "Industry 4.0". Science direct, Procedia Manufacturing 3. Pp. 417 - 424, Elsevier
[16] Ashraf N. & Camerer C.F. & Loewenstein G., 2005. Adam Smith, Behavioral Economist. Journal of Economic Perspectives—Volume 19, No. 3.Pp. 131 - 145. P. 131
[17] Mill, John Stuart. "On the Definition of Political Economy, and on the Method of Investigation Proper to It," London and Westminster Review, October 1836. Essays on Some Unsettled Questions of Political Economy, 2nd ed. London: Longmans, Green, Reader & Dyer, 1874, essay 5, paragraphs 38 and 48.
[18] Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review
[19] Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review

insurance attractiveness and entrepreneurship.[20] Two decades later, John von Neumann and Oskar Morgenstern introduced the fundamentals of game theory, which deals in situations where decisions are influenced by unknowable decisions of "live variables".[21] This view from von Neumann and Morgenstern of economic behavior in a strong rational and mathematical approach means, that decision-making follows purely utility maximization. The theory of von Neumann and Morgenstern explains a rational behavior of market participants (either consumers or entrepreneurs). Today mathematical models of rational theories were further developed on the essential foundation of these theories. John F. Nash developed these ideas to „Nash Equilibrium", which expresses the economic idea, that people act in accordance with their incentives. Furthermore John F. Nash showed that each finite game allows one solution. Finally, he implemented the fundamental distinction between cooperative games (binding agreements are supposed) and non-cooperative games (binding agreements are not possible).[22] Hand in hand with more sophisticated models, technology supported these models with increasing processing power, from decision support tools to artificial intelligence or deep learning systems.[23]

In these times, a different development on decision-making occurred, with an emotional (behavioral) view on decision-making. Based on observations, most decisions are made by humans and a reflection of their behave on making decisions. The research question appeared, if humans decide based on pure rational thoughts and utility maximization. The understanding of cognitive limitations of human brains, with first ideas of Simon, got an important place in research. In the late 1940ies Simon discussed the theory of bounded rationality, which means an influence of human attitudes and cognitive limitation without pure rational decisions.[24] Rejecting the classical notion that decision makers behave with rationality and utility maximization, Simon argued, because of the costs of acquiring information, executives make decisions with only "bounded rationality" - they make a decision „good enough".[25] Reaching a broader audience in science, more disciplines were analyzing decision-making from their own's perspective. Psychology science shows that theories on behavioral economy are currently popular, because human behavior is the most important part of organizational actions. In the 1970ies David Kahneman and Amos Tversky developed different theories of decision-making from a psychological perspective. The idea of prospect theory is a behavioral approach in decision-making. The theory of Kahneman and Tversky demonstrates that market participants do not act as rational as assumed from economist's. Stimulated from psychologists, economic researchers used these ideas to draw further conclusions based on the economical background. Reinhard Selten or Gerd Gigerenzer, researchers of behavioral economics used these different ideas to analyze decision structures in organizations in an economical context.[26] Based on the latest trend of digitalization, decision-making theory will face further developments which are worth to analyze and to discuss with researchers and practitioners.

[20] Roeser S. & Hillerbrand R. & Sandin P. & Peterson M., 2012. Handbook of Risk Theory - Epistemology, Decision Theory, Ethics, and Social Implications of Risk. Springer Science Business Media B.V. Aachen, Germany.
[21] Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review
[22] Van Damme E. & Weibull J., 1995. Equilibrium in Strategic Interaction: The Contributions of John C. Harsanyi, John F. Nash and Reinhard Selten. Scandinavian Journal of Economics 97(1). P.s 15-40. P. 16.
[23] Kaplan Jerry. 2016. Artificial Intelligence – What Everyone Needs to Know. New York: Oxford University Press
[24] Simon H.A., 1997. Administrative Behavior. New York: The Free Press
[25] Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review
[26] Gigerenzer G. & Selten R., 2001. Bounded Rationality – The Adaptive Toolbox. USA: MIT Press

1.1.2. Definition of Decision-Making

The rational view on decision-making, starting from the early economists, began with the definition of utility maximization. In the 1870ies, through the work of Jevons, Menger and Walras, utility maximization began to become important in economic analysis. For these three researchers, utility was a shortcut to a theory of value.[27] In the classical field of the economical view on decision theory, a rational, mathematical based approach is widely discussed and accepted. The assumption for calculations is, that individuals desire to obtain a maximum of utility or profit. Individuals who attempt to reach this utility maximization is defined "to act rational".[28] First of all, an overview of the basic elements of a decision model concept will increase the understanding of the concept, as shown in figure 1-1 "Basic Elements of a Decision Model".

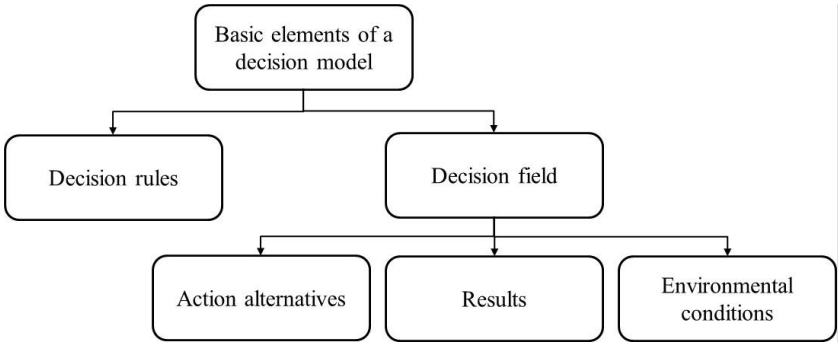

Figure 1-1 **Basic Elements of a Decision Model**

(Source: Author's construction, based on Bamberg G., 2012)

The basic elements of a decision model consist of decision rules and decision field. Defining the decision field leads only to a decision problem, if there are minimum two alternatives. Hence a determination and evaluation of these alternatives must be reflected in the decision model. A result will lead to a selection of alternatives.[29]

Environmental conditions are important to determine. Measures are not manipulable by the decision maker and these measures are called decision relevant data. These data are no variables of the decision maker, though these characteristics are decision relevant environmental conditions. The illustration of figure 1-2 "Structures of Environmental Conditions"[30] shows different environmental conditions. The conditions are distributed in certain and uncertain decisions, in which uncertain decisions can be divided in decisions under risk (calculable) and decisions under uncertainty (not calculable).

[27] Blume L.E. & Easley D., 06-2007. Rationality. https://www.ihs.ac.at/publications/eco/visit_profs/blume/rat02.pdf Accessed: 17.01.2018
[28] Neumann von J. & Morgenstern O., 2007. Theory of Games and Economic Behavior – Sixtieth Anniversary Edition. Princeton: University Press. Pp. 8
[29] Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag
[30] Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag, P. 33

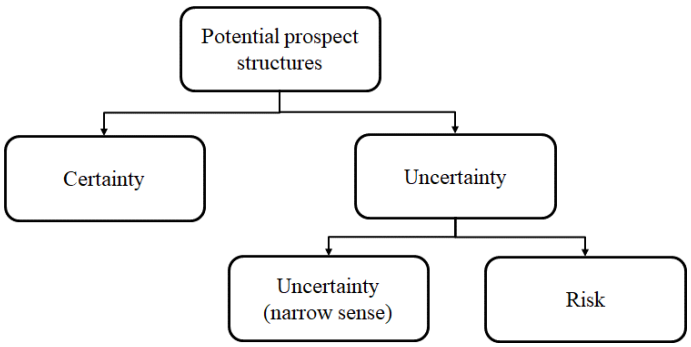

Figure 1-2 **Structures of Environmental Conditions**

(Source: Author's construction based on Bamberg G., 2012)

As described, a rational decision of the best alternative uses maximum utility. Decision rules define in the structure of the decision model how to select the best alternative, to reach maximum utility.

$$\Phi(A_a) \rightarrow Max_a \qquad \text{Formula 1-1}$$

Explanation: Search for the element A_a from the alternative quantity A, which maximizes the value of the preference function.

A decision structure under certainty means, the decision maker has the real condition of alternatives, all relevant information for the decision are given. The result is known and alternatives are certain.[31]

A decision structure under uncertainty means, that the decision maker has minimum two possible alternatives, but not all relevant information for this decision. The result is not known and alternatives are uncertain. In the case of uncertainty there are two more possibilities. Either for the decision maker it is not possible to calculate a likelihood of conditions (uncertainty – narrow sense) or for the decision maker the probability of occurrence of a condition is computable (risk). In these two chases various results are possible.[32]

This differentiation of the environmental conditions is important to define. While globalization creates a more complex world with an increase of uncertain decisions, a sophisticated model for decision-making is mandatory for organizations. In terms of digitalization a need for an algorithmic model is necessary, computers need a logic structure to calculate a result for a decision.

As an example, a further developed model, the Subjective Expected Utility Theory (SEU), a more subjective evaluation of variables under risk is possible. Both, variables under consideration and the probabilities comply to the concept of decision-making with an unknown probability. The situation of an unknown probability causes to the decision maker to estimate the probability of the result from available information to him.[33]

[31] Bamberg G. & Coenenberg A. & Krapp M., 2012. Betriebswirtschaftliche Entscheidungslehre. München: Verlag Franz Vahlen, P. 33
[32] Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag. Pp. 35
[33] Shanteau J. & Pingenot A., 2009. Subjective Expected Utility Theory. In Encyclopedia of Medical Decision Making. M.W. Kattan. Los Angeles. Sage Publications

The idea of a **rational (mathematical) view on decision-making**, was laid in history by various scientists, but descriptions of economic problems had been rarely constructed on a clear formulation. As von Neumann and Morgenstern state in their book „The Theory of Games and Economic Behavior": „The reason why mathematics has not been more successful in economics must, consequently, be found elsewhere. …the economic problems were not formulated clearly and are often in such vague terms as to make mathematical treatment a priori appear hopeless because it is quite uncertain what the problems really are." Hence von Neumann and Morgenstern describe a formulation for a mathematical approach: „It is not that there exists any fundamental reason why mathematics should not be used in economics".[34]Based on the above-mentioned structure of decision-making, different types are applicable. The different types of environmental decisions require a different type of calculation. First of all, a very structured type of decision-making – the decision under certainty – is simple to handle. All environmental conditions are known and the result is predictable for each alternative. In reality, most decisions are based on imperfect information, but these certainty models are important for scholar and practitioners.[35] For calculation of the optimal result Laux is defining a command variable matrix[36] or alternative for special cases Saatys method[37] is applicable. In reality, most environmental conditions are based on uncertainty, because of unknown environmental conditions. Decisions under uncertainty have two different conditions, decisions under uncertainty (narrow sense) or decisions under risk, as shown in figure 1-2 „Structures of Environmental Conditions". Decisions under uncertainty (narrow sense) are conditions or results with positive probabilities, but these probabilities are not possible to enumerate. In contrast to decisions under risk, which are possible to calculate with probabilities. For decisions under uncertainty (narrow sense) various calculations are possible, as maximin or maximax rules from Wald, Hurwicz principle, Niehans-Savage or Laplace rule.

The second condition of decisions under uncertainty is referring to risk. The main idea is going back to Bernoulli, with feasible axioms of rational behavior which enables to consider all possible command variables. Further research of von Neumann and Morgenstern, the foundation of axioms and plausibility, the Bernoulli principle is the most important normative decision criterion.[38] [39] [40]

The application of these theoretical ideas from the main thinkers of decision-making theory, may be found exemplarily in the case of operations research. In many ways the contribution of operations research and management science to decision-making theory had been very pragmatic for management, making better decisions. One example of a pragmatic technique that has proved itself very useful, and has been rapidly and widely adopted over the past years, is the scheduling procedure called PERT, or

[34] Neumann von, J. & Morgenstern O., 2007. Theory of Games and Economic Behavior – Sixtieth Anniversary Edition. Princeton: University Press. Pp. 3
[35] Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag. P. 57
[36] Command variable Matrix = Zielgrößenmatrix - Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag. P. 58
[37] Bamberg G. & Coenenberg A. & Krapp M., 2012. Betriebswirtschaftliche Entscheidungslehre. München: Verlag Franz Vahlen, P. 60
[38] Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag. P. 113
[39] Neumann von, J. & Morgenstern O., 2007. Theory of Games and Economic Behavior – Sixtieth Anniversary Edition. Princeton: University Press. P. 83
[40] Selten R. & Orland A., 12-2015. Buyer power in bilateral oligopolies with advance production: Experimental evidence. Journal of Economic Behavior & Organization 122 (2016) Pp. 31–42. journal homepage: www.elsevier.com/locate/jebo

critical path scheduling. This technique does not use sophisticated mathematics, but is an improvement of the common sense, underlying the traditional Gantt chart.[41] Further implemented applications in business are the model of cost-benefit-analysis or risk assessment models. Especially these models are designed to calculate the maximal benefit, risk or utility.[42] Bayes developed statistical models for further calculations of probabilities, which today evolved into different optimization scenarios.

Emotional (behavioral) view on decision-making is quite in contrast to the rational view. First of all, **Bounded Rationality** was a cornerstone for the development of a new view on decision-making. „Humans and animals make inferences about unknown features of their world under constraints of limited time, limited knowledge, and limited computational capacities. Models of rational decision-making in economics, cognitive science, biology and other fields, in contrast, tend to ignore these constraints and treat the mind as a Laplacian superintelligence equipped with unlimited resources of time, information, and computational might.“[43] Further Reinhard Selten describes full rationality as a requirement of unlimited cognitive capabilities and a rational man is a mythical hero who knows the solutions to all mathematical problems and can immediately perform all computations, regardless of how difficult they are.[44] To understand the development from a rational view of decision-making to the aspects of an emotional view, it is important to analyze rational choice. It is the determining of available options and then choosing the most preferred one, according to some consistent criterion. We will find that by adding one empirical assumption, the problem of rational choice can be represented as one of maximizing a valued utility function. Rational choice is based on individual decision-making.[45] Rational choice is an idea, based on social and psychological perceptions, to reach maximum utility, by human decisions. Simon described in 1959 that the theory of rational choice in reality is very limited. To predict human behavior in a permanently changing environment. It’s not only necessary, to understand the goals of the person (utility maximization), moreover the behavior of the person in a dynamic environment had to be predicted. Various exercises have shown, that people are rational in simple situations, but with increasing complexity of the decision, rationality is limited. Simon sees limited cognitive capabilities and the usage of heuristics.[46]

The **psychological view on** decision-making is important. „On the negative side, fascination with the pure theory of rational choice has sometimes distracted attention from the problems of decision makers, who possess modest calculating powers in the face of a world of enormous complexity.“[47] Important developments in decision theory took place over the recent decades, a trend to a behavioral approach

[41] Herbert A. Simon. 03-1965. Administrative Decision-making. Source: Public Administration Review, Vol. 25, No. 1, Twenty-Fifth Anniversary Issue (Mar., 1965), pp. 31-37. Published by: Wiley on behalf of the American Society for Public Administration. URL: http://www.jstor.org/stable/974005. Accessed: 30.10.2017
[42] David H. Jonassen. 04-2012. Designing for decision-making. Source: Educational Technology Research and Development, Vol. 60, No. 2 (April 2012), pp.341-359 Published by: Springer Stable URL: http://www.jstor.org/stable/41488586 . Accessed: 30.10.2017
[43] Gigerenzer G., 2001. The Adaptive Toolbox. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT, P. 37
[44] Selten R., 2001. What Is Bounded Rationality?. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT, P. 14
[45] Levin J. & Milgrom P., 2004. Introduction to Choice Theory. http://web.stanford.edu/~jdlevin/Econ%20202/Choice%20Theory.pdf. Accessed 15.03.2016
[46] Herbert A. Simon: Theories of Decision-Making in Economics and Behavioral Science. In: The American Economics Review. Band 49, Nr. 3, 1. Januar 1959, Pp. 258
[47] Herbert A. Simon. 03-1965. Administrative Decision-making. Source: Public Administration Review, Vol. 25, No. 1, Twenty-Fifth Anniversary Issue (Mar., 1965). Pp. 31-37. Published by: Wiley on behalf of the American Society for Public Administration. URL: http://www.jstor.org/stable/974005. Accessed: 30.10.2017

was supported by the discipline of psychology. An outstanding contribution to the development of behavioral economics was made by Kahneman and Tversky. In their pioneering paper „Prospect Theory: An Analysis of Decision Under Risk“, the idea of prospect theory postulated the contradictory position to above mentioned idea of utility maximization. This paper represents a critique of expected utility theory as a descriptive model of decision-making under risk, and develops an alternative model, prospect theory. [48] This theory rebuts the models and theories of utility maximization, because human decisions are not based on rational behavior. Humans have a different view on probabilities (estimation) than mathematical models (precise calculation), e.g. Bernoulli or Fermat. The own opinion of a person is important and will influence the own expectation of the related probability.

Current research and work in decision-making has clearly shifted from representing choice processes via normative models to an emphasis on heuristic processes, developed within the general framework of cognitive psychology and theories of information processing.[49] In the following a selection of these heuristics are named, to get an of manifold views on choice theory. Further aspects as representativeness, causality and attribution[50], availability[51], covariation and control[52], overconfidence[53] and mount stupid[54], multistage evaluation and corrective procedures[55], risk perception[56] are psychological theories in decision-making and relevant in science and practice, but will not be covered in depth.

As an example, **Prospect Theory** of Kahneman and Tversky developed a model with a structure of two systems. Depending on the activated system in the mind, which was named system 1 and system 2. System 1 operates automatically and quickly, with little effort and no sense of voluntary control”, e.g. answer of 2 + 2 = x, drive on an empty road, orient the source of a sudden sound. And system 2 allocates attention to effortful mental activities that demand it, including complex computations. The operations of system 2 are often associated with the subjective experience of agency, choice, and concentration, e.g. tell someone your mobile number.[57] Human structure is based on usage of system 1 to maximize efficiency and reduce unnecessary work for the brain. Only if it’s really required for a complex activity which is not answerable, system 2 is activated. This evolutionary approach was necessary to reduce the consumption of energy for the entire organism in a world with limited access to resources and energy. This evolutionary stage of our brain is still valid today and leads to discussed bias and heuristics. This

[48] Kahneman D. & Tversky A., 03-1979. Prospect Theory: An Analysis of Decision Under Risk. Econometrica. Mar 1979; 47, 2. Pp. 263 - 291
[49] Einhorn H., 2008. Learning from experience and suboptimal rules in decision-making. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. P. 268
[50] Kahneman D. 6 Tversky A., 2008. Causal schemas in judgments under uncertainty. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. Pp. 33
[51] Ross L. & Anderson C. A., 2008. Shortcomings in the attribution process: On the origins and maintenance of erroneous social assessments. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. PP. 117
[52] Oskamp S., 2008. Overconfidence in case-study judgments. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. Pp. 287
[53] Cohen J. & Chesnick E.I. & Haran D., 2008. Evaluation of compound probabilities in sequential choice. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. P. 355
[54] Dunning D., 2011. The Dunning Kruger Effect: On Being Ignorant of One’s Own Ignorance. Advances in Experimental Social Psychology. Volm. 44. Elsevier Inc. P. 260
[55] Fischhoff B., 2008. For those condemned to study the past: Heuristics and biases in hindsight. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. Pp. 287
[56] Slovic P. & Fischhoff B. & Lichtenstein S., 2008. Facts versus fear: Understanding perceived risk. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. Pp. 287
[57] Kahneman D., 2011. Thinking, Fast and Slow. UK: Penguin Random House. Pp. 20

concept of “system 1 and system 2”, sets the basis for a human behavior of decision-making, which absolutely defers from rational decision-making explanations above. Continuing this idea, the question what prevents a rational decision should be answered with Kahneman and Tversky’s prospect theory. The fact, that lot of decisions have both elements, a risk of loss and an opportunity of gain, effects a decision to gamble or deny. Focusing on loss aversion means, people avoid losses while there is a huge opportunity to gain the particular option. As a result, people deny this option and this is controversial to rational choice, where a pure calculation of probability should take place. The “optimistic bias” means, chances for success are overestimated. Risks are undervalued or not in scope of the decision maker and leads to a decision with a higher risk as in the cognition of the decision maker.[58]

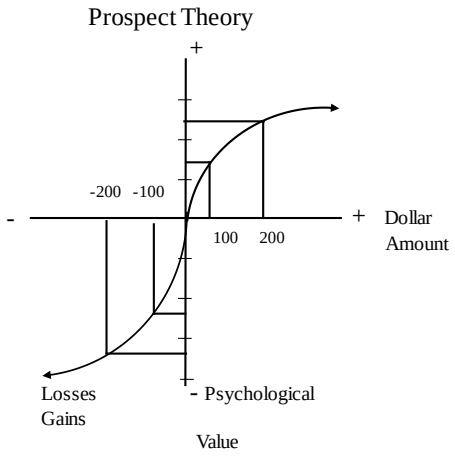

Figure 1-3 **Prospect Theory**

(Author’s construction, based on Kahneman D. and Tversky A., 1974)

Figure 1-3 „Prospect Theory“ explains the loss aversion theory and as opposite to a rational decision it is not a straight line, as expected in a rational model. The chance of losses and the chance of gains is moving the line, with a peak to losses. The graph is showing the effects, first the psychological value of gains and losses as carriers of values (as opposite Bernoulli stated wealth as carrier of value). Reduced sensitivity for gains and losses and the slope of the function changes at the reference point. Further the response to losses is stronger than the response to corresponding gains (loss aversion) and the two curves of the S are not symmetrical. Prospect theory is only one example, raised in the context of behavioral decision-making. Further effects were discussed from Kahneman and Tversky, e.g. adjustments, anchoring or frames, but will not be discussed in detail. Many ideas were based on these fundamental theories and contributed to this scientific field. Important for the author is, that human decision making is not as rational as expected in the theory of economists.

This opposite view to a rational decision process raises the question how the decision process in organizations is in reality. Are organizations as rational as assumed or are organizations emotional driven by their members with individual decision-making.[59] A useful contemporary source of behavioral decision-making, with human limitations and emotional influence on decision-making from Kahneman,

[58] Kahneman D. & Tversky A., 1974. Judgment Under Uncertainty: Heuristics and Biases. Science, New Series, Vol. 184
[59] March J. & Simon H.A., 1997.Organizations. Cambridge and Oxford: Blackwell

Slovic and Tversky is the book „Judgement under uncertainty: Heuristics and biases“ with an excellent overview of different influencing factors for this kind of decision-making.[60] Heuristics explain decision-making, despite of limitations of knowledge or time, but reaching a result toward utility maximization. Bias is a systematic error in a system and will lead to wrong assumptions for reaching utility maximization. „Intuition is simply a skill in recognizing those things that have become familiar through past experience.“[61]

A social examination of decision-making is not a part of this dissertation, because understanding the behavioral influence on decision-making of individuals differ from groups, but biases from group decisions are critical as well as biases from individual decisions. Nevertheless, group decisions are important today, the idea to overcome complexity with an increased quality of a group decision is valid under dedicated preconditions.[62]

1.1.3. Theoretical Analysis of Decision-Making in Organizations

The general definition of organizations in context of decision-making is, organizations are systems of coordinated actions among individuals and groups whose preferences, information, interests or knowledge differ. Organizational theories describe the conversion of conflict in corporations, the mobilization of resources, and the coordination of effort that facilitate the joint survival of an organization and its members. Effective control over organizational processes is limited by uncertainties and ambiguities of life, especially in business, by the limited cognitive and affective capabilities of human actors. Moreover, the complexities of balancing tradeoffs across time and space, and the threats of competition are in scope.[63] The decision-making process in organizations is a key task for managers and organizational members. The structure is made by humans and reflects human behavior in organizations. James March and Herbert Simon grouped in their book „Organizations“ three classes:

1. Organization members are primarily passive instruments; performing their work and accepting direction, but not initiating actions.

2. Organization members bring their own attitudes, values and goals into the organization.

3. Organization members are decision makers and problem solvers.

Understanding the types of organizational members, it is important to design the decision process in organizations. The theoretical process is designed by March and Simon in the following steps.[64]

1. Problem definition: a decision maker realizes, that a situation is not satisfactory

2. Specification of the target system: Targets will be formulated for the defined goal

[60] Kahneman D. & Slovic P. & Tversky A., 2008. Judgement under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. 24th printing.
[61] March J. & Simon H.A., 1997. Organizations. Cambridge and Oxford: Blackwell. P. 11
[62] Ambrus A. & Greiner B. & Pathak P., 05-2009. Group versus individual decision-making: Is there a shift? https://www.sss.ias.edu/files/papers/econpaper91.pdf. Accessed: 24.01.2018
[63] March J. & Simon H.A., 1997. Organizations. Cambridge and Oxford: Blackwell. P. 2
[64] March J. & Simon H.A., 1997. Organizations. Cambrigde and Oxford: Blackwell. P.158

3. Investigation of possible action alternatives: Search, analysis and prognosis for alternatives are designed, collected, calculated and analyzed

4. Choice of an alternative: Based on the target system, the best alternative should be chosen

5. Decision in the realization phase: still while realizing the alternative, decisions have to be made and followed up

Following this process, a high probability is given, that the maximum utility for the decision will be made, because by process design, human decision-making shortcomings may be limited. As Simon explains, "all decision is a matter of compromise" [65], is exhibiting the idea of a decision-making process to reach utility maximization. This opposite view to a rational decision process raises the question how the decision process in organizations is really made. Are organizations as rational as expected or are they emotional driven, which has effects on the result of decisions. In an organization with different interests of members, the question of a maximum utility for the decision problem has to be questioned, and finding a sustainable solution for all involved parties is more probable. The environment of the organization limits the alternatives and maximum utility due to compromises.

The question, how to **measure increased efficiency of decision-making** is a relevant question for this dissertation. Efficiency is defined a as assessment criterion of a measure to reach a target in a defined way with optimized effort.[66] In detail, the measurement of improved decision-making is focus of the hypothesis and associated analysis of empiric data. These decision rules and guidelines have been broadly defined as strategy[67], based on Igor Ansoff, „a strategy is a set of decision-making rules for guidance of organizational behavior."[68] Therefore, decision-making is not based on immediate actions, it rather sets general direction to position the organization.[69] These decisions will set the mainframe for an organization and will contribute to a long-lasting development of this organization. Successful decision-making is the foundation for a successful organization. The measurement of decisions is based on KPIs and should be flexible for every application case, as defined in the model definition.

1.2. Theoretical Analysis of Digitalization

The mega trend of digitalization is capturing every aspect of daily life. For a consumer's environment digitalization is respecting almost all areas of their actions to reach „maximum utility" or even satisfaction. For business organizations, digitalization is even more important, because not using the applications of digitalization, businesses will receive disadvantages in their competitive position. The

[65] Simon H.A., 1997. Administrative Behavior. Cambrigde and Oxford: Blackwell. P. 5
[66] Gabler Businsess Dictionary. https://wirtschaftslexikon.gabler.de/definition/effizienz-35160 Accessed: 29.03.2021
[67] Ansoff H.I., 1986. Corporate Strategy. McGraw-Hill. London. P. 94
[68] Ansoff H.I. & McDonnell E.J. 1990. Implanting Strategic Management. Prentice Hall International (UK) Ltd, Hertfordshire. P. 43
[69] Ansoff H.I. & McDonnell E.J. 1990. Implanting Strategic Management. Prentice Hall International (UK) Ltd, Hertfordshire. P. 43

internal view (lack of process efficiency) and the external view (missed market opportunities) have to be on the digital roadmap of every organization in today's business world. Increased competition is faced by all organizations and need to be answered by a digital roadmap of organizations, otherwise organizations will lose their opportunity to exist and disappear from the market.

1.2.1. History of Digitalization

The trend of digitalization is a new phenomenon of the recent years or decades, but organizations were always focused on process efficiency and input/output optimization. Starting some centuries back, the foundation for digitalization and its evolving steps started with Gottfried Wilhelm Leibnitz. He developed the modern binary number system and published in 1703 „Explication de l'Arithmétique Binaire". Based on this work, he developed a calculating machine, with a binary system, the starting point for a new discipline.[70] In 1847 George Boole introduces Boolean algebra in „The Mathematical Analysis of Logic", creating the field of mathematical logic and thus leading to universal computation.[71] 1937 Claude Shannon submits his master's thesis at MIT, establishing the theoretical underpinnings of digital circuits. Shannon showed how Boolean algebra could optimize the design of systems of electromechanical relays and then used in telephone routing switches. In 1940 John V. Atanasoff wrote in „Computing Machine for the Solution of Large Systems of Linear Algebraic Equations", a paper describing the electronic digital calculating machine. [72] He has built - together with Clifford Berry- the first computer. Atanasoff wanted to increase the speed and accuracy of scientific calculations through the development of an electronic digital computer. Based on this idea, Clifford Berry and John Vincent Atanasoff designed the "ABC", the first digital computer. [73] Just a few years later, in 1945 John von Neumann's paper „A First Draft of a Report on the EDVAC" was a further development of a computer. This article documents the key decision for the design of the EDVAC, to use binary code to represent numbers. The new direction of processing became the new technological basis for all modern computers.[74] Further on, in 1948 Claude Shannon published "A Mathematical Theory of Communication". As Claude Shannon explained, „If the base 2 is used (for measuring information) the resulting units may be called binary digits, or more briefly bits, a word suggested by J. W. Tukey. A device with two stable positions, such as a relay or a flip-flop circuit, can store one bit of information." That was the moment introducing bits and bytes to scientific foundation of computing. The first computer used for a business application was implemented in 1954 in Louisville from General Electric's major appliance division plant and installed the UNIVAC I computer. This computer was able doing payroll processing and manufacturing control programs. From now on, the implementation of computers in organizations was a huge trend and exemplarily in 1955 John Hancock Mutual Life Insurance Co., a

[70] Achievements of Gottfried Wilhelm Leibnitz. http://www.nlb-hannover.de/Leibniz/Leibnizarchiv/Leben_und_Werk/ Accessed: 14.02.2018
[71] Grattan-Guinness I. & Bornet G., 1997. George Boole - Selected Manuscripts on Logic and its Philosophy. Birkhäuser Verlag. Basel. Accessed: 14.02.2018
[72] Boyanov K., 2003. John Vincent Atanasoff – The Inventor of the First Electronic Digital Computing. International Conference on Computer Systems and Technologies - CompSysTech'2003 Accessed: 14.02.2018
[73] „Atanasoff Berry Computer" . 2011. JVA Initiative Committee and Iowa State University. Accessed: http://jva.cs.iastate.edu/operation.php. Accessed:15.02.2018
[74] Von Neumann J., 07-1945. First Draft of a Report on the EDVAC. Moore School of Electrical Engineering University of Pennsylvania. June 30, 1945.: https://www.wiley.com/legacy/wileychi/wang_archi/supp/appendix_a.pdf. Accessed 15.02.2018

pioneer in digitizing customer information, digitized 600 megabytes of two million life insurance policies. Then an organization, which is still today known as a computer company - IBM - announced in 1956 the 350 Disk Storage Unit, the first computer storage system based on magnetic disks and the first to provide random access to stored data. It came with fifty 24-inch disks and a total capacity of 5 megabytes, weighed 1 ton, and could be leased for 3.200 USD per month. The first customer was United Airlines' reservations system. IBM promised, that business transactions will be completely processed right after they occur. In 1962 the term database is mentioned for the first time, according to the Oxford English Dictionary, quoting „A 'data base' is a collection of entries containing item information that can vary in its storage media and in the characteristics of its entries and items."[75]

An important theoretical contribution to computer science was made in 1965, when Gordon Moore published "Cramming more components onto integrated circuits" in Electronics magazine. This was the first formulation of the known "Moore's Law." The observation of constant doubling the number of transistors, that can be "crammed" into an integrated circuit. It became a guideline of manufacturing process innovations that have reduced the price and increased the power of electronic components. Not only the physical aspect (hardware) of computer science was a driver for this development. More important became the aspect of the digital part of it, software development. In 1970 the foundation of a basic concept was introduced, a relational model of data basis, which had been dominant until the 2000er years, by Edgar F. Codd. The view from Charles Bachman „a new basis for understanding is available in the area of information systems. It is achieved by a shift from a computer-centered to the database-centered point of view. This new understanding will lead to new solutions to our database problems and speed our conquest of the n-dimensional data structures which best model the complexities of the real world."[76] The digital components were developed to products and applications for consumers and business, as displayed in the table 1-1 „Digital Product Innovation over Time".

[75] Ryan M.-L. & Emerson L. & Robertson B.J., 2014. The Johns Hopkins Guide to Digital Media. John Hopkins University Press, Baltimore, Maryland. P. 127
[76] Burkhardt M., 2015. Digitale Datenbanken – Eine Medientheorie im Zeitalter von Big Data. Transcript Verlag, Bielefeld, Deutschland. P. 38

Digital Product Innovation over Time *Table 1-1*

Year	Application	Features	Organization
1972	Digital watch	All-electronic watch including a digital display.	Pulsar
1975	Digital camera	23 seconds to capture an image on compact cassette tape. Weight of 8 pound and 0,01 megapixels.	Eastman Kodak
1977	ATM	= Automated Teller Machine. 24-hours cash dispenser.	Citibank
1979	COSMOS	= Customers, Operations, and Services Master Online System. Digitizing the management of people, packages, vehicles, and weather scenarios real time	Federal Express
1982	CD	= Compact Disc. Digitalization of voice from analogue sound recording mediums.	Philips
1990	HDTV	= High Definition Tele Vision. A digital signal for conventional broadcast channels.	General Instruments
1991	Cellular Phones	2G networks used digital signals rather than analog transmission of mobile phones and cellular towers.	Nokia
1992	Internet	Tim Berners-Lee posts the first photo uploaded to the Web.	CERN
1996	Internet Shopping	A large pepperoni, mushroom and extra cheese pizza is ordered online, the first transaction on the Web.	Pizza Hut
2000	MP3	A digital audio news and entertainment service called MyAudio2Go.com that enabled users to download news, sports, and music in audio format.	i2Go
		Internet Development	
2007	Digital Storage	94% of the world's information storage capacity is digital, a complete reversal from 1986, when 99.2% of all storage capacity was analogue.	
2008	Digital Payment	Satoshi Nakamoto publishes "Bitcoin: A Peer-to-Peer Electronic Cash System", describing the first decentralized digital currency.	
2012	E-commerce	Annual e-commerce sales top 1 trillion USD worldwide for the first time.	
2014	Internet user	The number of Internet users worldwide reached 3 billion people.	
2015	Internet usage (every minute)	Skype users make 110.040 calls Twitter users send 347.222 tweets YouTube users upload 300 hours of new videos Netflix subscribers stream 77.160 hours of video Snapchat users share 284.722 snaps Facebook users like 4.166.667 posts	

(Author's construction)[77]

[77] https://www.forbes.com/sites/gilpress/2015/12/27/a-very-short-history-of-digitization/6/#3ec551cc2e62 Accessed: 14.02.2018

As shown in the table above, these key developments changed the world from analogue to digital. A main driver of digitalization is efficiency, though in 1996 digital storage becomes more cost effective than storing data on paper. In the same time the first digital currency system was implemented, e-gold.

A further aspect of digitalization has to be taken into consideration, because legislation defined the framework for digitalization and is either a driver or a blocker to set boundaries, e.g. the "Check 21 Act". Over 50 billion paper checks were processed in the U.S. in 2003. In 2004 Google announces it is working with the libraries of Harvard, Stanford, the University of Michigan, and the University of Oxford as well as The New York Public Library to scan books from their collections. The Internet Archives starts a similar effort, the "million books project".

This historical view on development of digitalization over the recent decades is an important preparation for understanding the topic digitalization of decision-making. Drawing the bow from the first ideas of digitalization from Gottfried Wilhelm Leibnitz with his binary number system to the digital world today, the relevance of the topic is noticeable.

1.2.2. Definition of Digitalization

"Digitalization refers to the practice of taking processes, content or objects that used to be primarily (or entirely) physical or analogue and transforming them to be primarily (or entirely) digital. The effect of digitizing processes, aside from potential efficiency gains, is to make processes more tailorable and malleable".[78] A modern definition with a distinction between digitalization and digitization is given by J. Bloomberg. Digitization (technology) is defined as "Digitization essentially refers to taking analog information and encoding it into zeroes and ones so that computers can store, process, and transmit such information."[79] Digitalization (economy) is defined as "… the use of digital technologies to change a business model and provide new revenue and value-producing opportunities, …".[80] The era of digitalization determined a new business world with a change in division of work. Automation of our world in permanently ongoing, influenced by computers and machines. Important for the success was the definition of rules for computers, because computers are perfect in following algorithmic rules. Currently the speed of digitalization is increasing, either the trend of "Industry 4.0" with automation of the production flow[81] or artificial intelligence with robots, which make autonomous decisions.[82] Robots and machines are heading into our working environment and will replace human workers in a broader scope. The balance from division of work changed already but will change dramatically in the future,

[78] Fichman R. & Dos Santos B. & Zheng Z., 06/2014. Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. MIS Quarterly Vol. 38 No. 2. Pp. 329-353
[79] Bloomberg J., 04/2018. Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril. [Online] https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=6c338cba2f2c. Accessed 13.01.2022
[80] Bloomberg J., 04/2018. Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril. [Online] https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=6c338cba2f2c. Accessed 13.01.2022
[81] Zelinski P., 02/2016. Where 4.0 Might Go. [Online] http://www.mmsonline.com. Accessed 10.04.2016
[82] Lee J. & Kao H. & Yang S., 2014. Service innovation and smart analytics for Industry 4.0 and big data Environment. Science direct, Procedia CIRP 16 (2014). Elsevier. Pp. 3 - 8

though traditional professions will disappear, and new professions will appear. As a result, the structure of decision-making in organizations will change completely. Referring to the effects of digitalization, this trend will completely change the way of making business and making decisions. Flexibility and transformability are key attitudes of successful organizations in the future and drive them on the road of digitalization.[83] Digitalization will have an effect on customer structure and behavior, increase the efficiency of operations including the supply chain and at the end may change the entire business model of an organization or entire economies.[84]

Important to understand are the 4 areas of digital transformation: **smart data, automation, integration and digital customer access**. These 4 areas have to be in scope of decision-makers, because these are the corset of the digital change. [85] A fifth area had been added by the author, **digital business model**. The first area of digitalization - **smart data (big data) -** is a widely discussed topic in digitalization. Data collection itself is not new for organizations, this activity had been done since organizations are established in our society. Recording, processing and analysis of mass data, high-quality and more predictable forecasts, will lead to better decisions in organizations. The structure of smart data is mainly understood by five factors – **volume, velocity, variety, veracity and value**, as explained in table 1-2.[86]

The Five Factors of Smart Data *Table 1-2*

Volume	Refers to the **amount** of data generated. Today the measurement developed from old-fashioned giga- or terabyte to new levels of peta- and zettabytes.
Velocity	Refers to the **speed** at which new data is generated and the speed at which data are moved around the globe. A real time approach is getting more and more popular in organizations, even in production or organizations as „digital shadow“.
Variety	Refers to the different **type** of data. In the past the focus was mainly on structured data fitting into spreadsheets or databases. It's given that more unstructured data are available, e.g. sensor data, voice or sound recordings, images or videos. Latest tools are able to work with these unstructured data and will give exiting insights for new business models.
Veracity	Refers to messiness or **trustworthiness** of data. In the past, the analytics used only structured data, but now systems cope with unreliable data. This means latest technology needs to deal with inaccurate data.
Value [87]	Bernard Marr added a fifth „V“ to the big data context, meaning value. Looking at the latest developments of data increase, it is essential for organizations to generate insights out of these data. Pure data are worthless, only if an organization is able to bring order into these structures, an advantage for this organizations will be created.

(Author's construction, based on B. Marr)

[83] Bauer W. & Hämmerle M. & Schlund S. & Vocke C., 2015. Transforming to a hyper-connected society and economy – towards an "Industry 4.0". Science direct, Procedia Manufacturing 3 (2015), Elsevier. Pp. 417 – 424
[84] Westerman G. & Bonnet D. & McAfee A., 2014. Leading Digital. Boston: Harvard Business School Publishing
[85] BDI Research. 2015. Die digitale Transformation der Industrie; BDI – Bundesverband der deutschen Industrie
[86] Goes P. 07/2014. Big Data and IS Research. MIS Quarterly Vol. 38 No. 3, Pp. 3-8
[87] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 86

Smart data is a huge trend in the digitalization context, because the usage of data is important for an organization. As "The Economist" wrote in 2010, "Data are becoming the new raw material of business", and the volume of data is increasing day by day. A strong increase of data traffic has happened and will further increase. Due to an increase of smart applications, a further trend of digitalization will increase the volume of data, e.g. machine to machine communication or the trend of mobile data from every user of the Internet, who will permanently increase the traffic. Further definitions in the scope of data are important, especially for decision-making. The definition of structured data is important, because the development of unstructured and semi-structured data is increasing with the possibility to work with these data. Structured data is any data or information that is located in a fixed field within a defined record or file, usually in databases or spreadsheets, commonly managed using Structured Query Language (SQL)." This common data structure is well prepared in organizations, e.g. customer data, transactional records, financial data or production data. This type of data is a common standard today and create value to an organization, because the analysis of these data is quite simple. Structured data are only about 20% of all available data in the world. The flipside of the coin, the 80% of unstructured or semi-structured data, worth to analyze. Unstructured data are data which doesn't fit into traditional structured formats, spreadsheets or databases, e.g. photos, videos, audio recordings or even social media. Latest developments offer now, due to the increase of storage capabilities and the ability to tag and categorize unstructured data, the use of these data.[88] This trend is quite important for decision-making based on these data, because not to use 80% of available information, would cut the opportunity for a sophisticated decision process and competitive advantage. The cost for insights in these data seems even higher compared to structured data, but at the end, the quality of the decision will be improved.

Finally, a data segmentation into internal and external data seems constructive. Internal data refer to all information of an organization. These data are proprietary data and owned by the organization. Only the organization controls access to these internal data. Using these data is a big advantage in a competitive view, because nobody else can use these data. In the opposite, external data are existing outside an organization. These are public data and third parties are able to use these data too. For decision-making, the use of these different data segments is relevant. New types of data arising today, because everybody is tracing data every day. These new types of data are useful for organizations and the analysis of these data will change the approach of making decisions. Activity data are recorded online or offline from everybody, e.g. data of every single cell phone. Conversation data between participants are tracked, using social media or IP calls. Photo and video data are rising, because of features in smart phones, storing these data in data bases. The trend of sensor data for every aspect in life, private or business, is also rising, because tracking processes is in an efficiency driven world more important than ever. [89]

The second important area of digitalization, **automation,** is a trend, which is not completely new. Automation took place, since industrialization found the way in our modern society. The definition of automation is given, as transfer of tasks and functions of production processes, especially process

[88] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 88
[89] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 90

steering and control from human beings to automated systems. In detail, from a traditional view, mechanizing was the task of feeding energy to the production process. Over time, by development of new features and machines, process steering and control was a new task to be done by these systems, possibly with human interaction. Depending on the level of automation, the classification is split in partly or full automation. In the past, the focus had been on efficiency effects gained by automation of a rigid periodic production flow. Today a change is visible, because the focus moved toward flexible production systems.[90] Supported by the development of new systems and machines, this change to a higher flexibility is necessary, to meet customer and market requirements.

New trends of automation are appearing. First of all, robot technology or cyber-physical-systems with a high flexibility of tasks are appearing. A particular variant of a robot is a cobot, which means humans and robots will work in collaboration. These co-working possibilities are the latest trends and quite important from a regulatory view. Legislation defined the international standard ISO 10128. The combination of traditional work and latest technology will enable autonomous work in self-organized systems. As an effect, production speed and quality will increase, unit costs will drop. Automation has different aspects of realization. First, the relation of work between human workers and machines will change. Second, the trend toward a higher automation is ongoing, up to fully automated factories without human activities. The assumption that machine to machine connections will grow is given, and estimated by the year 2024 of 27 billion interactions between machines.[91] The third step, artificial intelligence, as a self-learning system, with the option to replace human employees.[92] All these developments will have an effect on decision-making. As example, a new technological process is rapid manufacturing, which means that traditional production procedures will be replaced by latest technology. This new technology uses directly digital data for production, without any tooling procedures. Cost intensive tools are replaced by new manufacturing applications based on digital data. These procedures are very flexible and cost beneficial, with an option for small batches down to batch size one.[93]

By the **combination of automation and smart data**, the effect for an organization is quite important. Using machine data, generated by sensors, meters or GPS devices, machine optimization is possible in real time and will push further efficiency gains in production.[94] The next step change for automation is the development of artificial intelligence, machine learning and deep learning, with a significant relevance for decision-making.

The third area of digitalization, **integration,** is a relatively new field in digitalization and had its breakthrough with the invention of the Internet, sending protocols between sender and receiver. The idea of a smart factory is introduced with the development of „Industry 4.0“, where cyber-physical-systems (a collaboration of computers, networks and physical actions) monitor physical processes of a

[90] http://wirtschaftslexikon.gabler.de/Archiv/72569/automatisierung-v7.html Accessed: 01.03.2018
[91] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 5
[92] Kaplan, J., 2016. Artificial Intelligence – What Everyone Needs to Know. UK: Oxford University Press
[93] Bopp F. 2010. Rapid Manufacturing: Zukünftige Wertschöpfungsmodelle durch generative Fertigungsverfahren. Hamburg; Diplomica Verlag
[94] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 26

factory and these systems will make decentralized autonomous decisions. Machines of a smart factory are equipped with web connectivity as part of the entire production chain (inter- or intra-company) and are able to make decisions in collaboration with each other. Communication is done between machines or with humans via real time web access. For a smart factory the following 4 features are necessary: [95]

1. Interoperability - machines, devices, sensors and people connect and communicate with each other
2. Information transparency - the system creates a virtual copy of the physical world, a digital twin
3. Technical assistance – ability to support and takeover difficult, unsafe tasks of humans
4. Decentralized decision-making – cyber-physical-systems make autonomous decisions

An important integration in the era of digitalization is a deeper collaboration in the entire supply chain. Based on flexible consumption behavior, an agile supply chain has to deliver this flexibility on an improved cost level. As result a strong inter-company collaboration is a must, and online information has to be exchanged between the partners. The cross-linking of organizations with their IT systems are the requirement for efficient supply chain management. Today's technology enables this process, based on standard software tools and open interfaces for an optimal data exchange between all related parties. A fast-changing world - with a drop of product life cycles - enforces a robust integration between supplier and customer as partners, because an inter-company product development process needs to have speed in "time to market" for a competitive and cooperative relationship.[96] RFID technology enables a permanent tracking of goods in the supply chain. Moreover, organizations have, based on this technology, full transparency of their inventory, also while transfer. Customers have a transparent tracking of their incoming goods for an improved material planning process.

The fourth area of digitalization, **digital customer access** is today in our monetarized world a key factor for success. Customer centricity should be a main activity for organizations. New competitors, new services and new market transparency will increase competition and the market position of companies or brands will be affected. Today, for a customer the next competitor is just one click away.

Customer Expectation: Me, All, Everywhere and Immediately *Table 1-3*

Me	**All**	**Everywhere**	**Immediately**
Appreciation as must	Wide choice	Time independence	Instant contacting
(correct) Personalization	High quality	Location independence	Fast transactions
Tailored offers	Low prices	Independence of technologies, channels, devices	Short response time
Based on permissions	Good service		

(Author's construction, based on Kreutzer and Land[97])

[95] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 11
[96] Wannenwetsch H., 2007. Integrierte Materialwirtschaft und Logistik. Neustadt: Springer Verlag
[97] Kreutzer R. & Land KH. 2015. Digital Darwinism – Branding and Business Models in Jeopardy. Berlin. Springer Verlag, P. 46

The trend of "smartization" is ongoing, making all devices intelligent via networks. Starting with mobile phones, developed to smart phones, up to today's development of smart TVs and smart watches. Even housekeeping is going smart, with refrigerators or washing machines, even energy consumption is steered with smart technology.[98] A great answer to these new customer requirements is developed from the e-commerce pioneer Amazon with its personalized recommendation system („customers also considered-function"), based on millions of customer data and transactions. This is an important combination of all digitalization areas for decision-making, because the influence of customers is more precise and creates a buying desire. Psychologists are talking about the power of suggestion.[99]

A further digitalization area, **new business models,** is an all-embracing view on organizations in a changing world. New business models are supported by digitalization trends, because every part of business is affected by these changes. There are two options to design a business model. New organizations will be faster and more innovative as existing organizations and should outperform these traditional businesses. For new businesses it is not a matter of change, they start immediately in the new environment with digital conditions and without ballast of history. It seems easier for new organizations to adopt to the "new world", but their risk is mainly the lacking source of financing new ideas and to implement these ideas into the market on an appropriate level, gaining profit out of these ideas. Existing organizations, which operated before the era of digital transformation, are facing a challenge to reach a digital business model with new concepts of doing business. These organizations stick in their structures which had been successful before the digital age. Transforming the business model is a huge task for management by convincing the whole organization and pushing them toward the digital transformation. Getting the commitment of the organization and then moving into this new competitive position is a stressful movement for the entire organization and its members. This change process is time and cost intensive for traditional organizations and the probability to fail is obviously given, because there are not only supporters for this new strategy. From a competitive perspective, these new business models, based on above mentioned digital elements of big data, automation, integration and digital customer access, will increase the challenge for all industries. Well known examples, as Amazon, reinventing the entire retail business, is a common business case today. As a result, for existing organizations, the challenge is, to adopt the current business model to the new world, either by reengineering the current model or to develop a completely new model. Ignoring this change, will destroy the known business model, e.g. a known example is Quelle shop in Germany. The precursor of an online shop, distributed a physical catalogue to consumers and they ordered manually. The move toward a digital solution failed, because the organization was not prepared to move to a digital business model. The more successful movement was done by Otto group, with exactly the same business model, but Otto group prepared the organization for the digital transformation. Today is Otto online shop number two in Germany with a revenue of 2.743 mio. EUR, only beaten by Amazon with a revenue of 8.123 mio EUR.[100]

[98] Kreutzer R. & Land KH. 2015. Digital Darwinism – Branding and Business Models in Jeopardy. Berlin. Springer Verlag, Pp. 6

[99] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. P. 26

[100] https://www.ehi.org/de/top-100-umsatzstaerkste-onlineshops-in-deutschland/. Data are based on revenue figures of 2016. Accessed: 09.07.2018

The final view on digitalization areas is not less important than the explanation of every dedicated area before. For the author it is essential not simply to focus on every single digitalization area as an isolated treatment. The view wouldn't respect the full effect of digitalization. Very important is the view on digitalization and its areas as a whole and the combination out of these areas. Especially the citation of Aristotle seems quite important for this case of „the whole is more than the sum of its parts"[101]. This means exemplarily for the combination of automation and integration, to realize the idea of machine-to-machine communication. A further view is the combination of customer journey and smart data, to design customized product offers to consumers like Amazon designed its personalized recommendation system („customers also considered"-function). Finally, the creation of new business models maybe the combination of all areas, e.g. Facebook, Snapchat, etc.

The **definition of an „intelligent digital setup"**, has to be introduced in a comprehensive manner. The definition of "intelligent" is in this context quite important, because in a digital environment "intelligent" has a second meaning in regards of machines and especially in the context of artificial intelligence. In this view act machines on an autonomous level. The definition of "intelligent" in the research question and the hypothesis is based on „revealing or reflecting good judgment or sound thought: skillful"[102]. This meaning of skillful or clever describes a good thought out approach, depending on the organization's environment. The definition of "digital" is given in this chapter above and is still the basis for the idea, that everything what is analogue or manual will be transferred into digital solutions. The definition of "setup" is a very general expression for the entire digital environment, from hardware to software including digital processes. This means, that an "intelligent digital setup" of an organization is always individual, because of the individual conditions of an organization. As an example, cited the interview with an CFO, that the customers of an organization are not focused on digital processes and the order intake will be processed by telephone or fax.[103]

1.2.3. Influencing Factors of Digitalization of Decision-Making

The phenomenon of digitalization of decision-making is significantly increasing with a new relevance for organizations. For this dissertation, the drivers behind this development are important to analyze, to direct research question and hypothesis in an appropriate context. The appearance of digitalization of decision-making has - from the author's view - manifold reasons and influencing factors are relevant for a better understanding of the research topic. The relevant influencing factors will be captured in this chapter, to prepare the definition of research question and hypothesis. Organizations, especially in a competitive environment, pursuit for efficiency and revenue increase to defend or extend their competitive position. Efficiency is relevant in all functions, starting in the production process up to general functions, for durable cost reductions. A further activity to improve profit, is to focus on revenue opportunities. These two strategies have to be embedded in an organization to succeed in the market.

[101] Cit. Aristotle.
[102] https://www.merriam-webster.com/dictionary/intelligent Accessed: 10.04.2018
[103] Dryden S., 2016. Interview in case of the prestudy by Hoßfeld S.

Influencing factors for these decisions are important, for the performance of a decision. Based on these decisions, influencing factors are today even more important than in the past, because understanding these influencing factors, will organizations lead to self-determined success. For a broad understanding table 1-4 „Influencing Factors of Digitalization of Decision-Making" shows the most important influencing factors for digitalization of decision-making. These influencing factors should be evaluated, if a digitalization strategy is relevant for efficiency gains. Sometimes, not all aspects are reasonable to digitize, e.g. customer loyalty is an emotional aspect in decision-making and maybe not the preferred topic to digitize.

Influencing Factors of Digitalization of Decision-Making *Table 1-4*

Influencing Factor	**Details**
Emotion	Second best solution (Gigerenzer) Heuristics & biases (Kahneman) Overconfidence (Gigerenzer) Loss aversion (Kahneman) Relationship management
Complexity	Globalization New markets New competition (Porter) New customer behavior (Kreutzer & Land)
Response time	Shorter decision paths Quick time to market High innovation rate Shorter product life cycle
Technology	Increased calculation performance Integration (machine-to-machine communication) Usage of smart (big) data Automation of processes (Fraunhofer IAO)
Organization	Matter of compromise (Simon) Increasing size of organizations Organizational development Future setup (Brynjolfsson) Corporate governance and transparency (legislation)

(Author's construction)

Emotional factors are very important in decision-making, as covered above, with a description of emotional decision-making. This topic shows, as discussed, two sides of the same coin, because sometimes emotions are important, but sometimes emotion should be avoided in decision-making. The view, to avoid emotional decisions was explained before and its limitations to reach utility maximization. Amongst others, Kahneman and Tversky have shown with their ideas of heuristics and

biases, that humans yield the misinterpretation of their brain. Also, Gigerenzer explained in detail how humans draw their decisions with cognitive limitations and are not able to reach maximum utility. Gigerenzer is contributing „gut feelings“ to the scientific discussion, and leads to a set of learned heuristics in our brain. Contradictory, the deep wish of managers, to rationalize decisions beyond emotions is important and the ideas are shown in the first part of this dissertation. Fact based information with increased transparency is a goal for decision-making in organizations. On the other hand, emotional factors should partly remain in the decision process, when it's better to use emotional intelligence for decisions. This is the case when decisions are less operationally driven and more related to human or emotional interaction, respectively people relationship. Therefore, having today the opportunity to select from both possibilities, either to use digital or human decisions, should increase the quality of all decisions and the opportunity to reach maximum utility in total. Management has to define, if a decision should be done manually or even digital by machines. Finally, a hybrid process is possible, to prepare a decision by machines and then to make the final decision by humans (decision support system).

The trend of globalization is a main driver for digitalization and creates **increased complexity**, because the possibility of global sourcing is today a realistic opportunity for all sizes of organizations. In the past, a global sourcing was limited to global organizations, but today, all organizations have the opportunity to source on a global scale. As a result, the global flow of goods increased. Related to globalization, new markets, suppliers and customers are appearing, because the digital world is connected without limitations. There is only one obstacle, if the organization is not visible in the Internet, then this organization seems not to exist and will remain on a local level. Mainly new customer behavior increases complexity, based on the digitalization area „digital customer access“, as discussed in the chapter before. Organizations should transfer their statements to the customer and have to listen to the customer and then manage the customer. Today with increased customer transparency a customized message to each customer seems more effective than general statements for an entire market.

In a digital world, two forces - the threat of new entrants as well as the threat of substitutes - are both severe enough to keep CEOs awake at night, because competition is not known today and may slop from a different industry into the own industry. Meanwhile, the bargaining power of suppliers shrinks in a digital environment. Physical components are becoming commoditized - and even replaced - by software, so the suppliers of those components are becoming less important and their bargaining power is declining.[104]

The topic **response time** in decision-making is correlated to customer expectations, because the speed of market response is increasing steadily and therefore organizations won't be longer successful with a long-lasting decision process. Qualities, features, prices of goods and services aren't anymore as different as in the past without digital possibilities of comparison. If products and services are on a similar level, then the fastest market participant will make the deal, because customers are not willing to wait for a second solution in the market. This is today a typical trend for online businesses. If goods are not available immediately, customers are not willing to wait, consumption or procurement will be

[104] „Digital Transformation of Business“. 09-2015. Trends E-Magazine. Pp. 1-6

finalized with the first partner, which is ready to make the deal. Another important aspect of speed is a high and fast rate of innovation. This innovation rate is becoming more and more important, because as explained above, product distinction is currently the challenge for organizations in a transparent market with a tremendously high imitation rate. Consequently, it's vital for organizations to introduce new products in the market with an appropriate speed. This development of new products and new product features, should be focused on smart aspects of the product or service. Because of these high innovation rates, product or service life cycles are shrinking and the market pressure to innovate on a higher rate has to be reflected. For a profitable view on this development, it's important to reach financial break-even of a product or service as soon as possible, because of a short life cycle and the limited time for returns of product development. Supply chain management should support these requirements of organizations, as a strategic function of an end-to-end process. The need for corrective actions is transparent within supply chain management.

The increasing technological progress (**technology**) is the main driver for digitalization. As indicator, Moore observed the number of transistors in a dense integrated circuit doubles approximately every eighteen months. This increased calculation performance changed the possibilities for applications in a digital environment, no matter of a complete digital solution or a cyber-physical-system. Based on the increased calculation performance, the connection between the cyber space and the real world increased dramatically and reflects the real world in some areas in the cyber space, e.g. digital twins or digital shadows. If Moore's law will come to an end or will be confirmed in the next years is a debate between experts and professionals. The view, that physical limitations will break Moore's law or if these limitations will be resolved will show the future development and innovative research of public and private organizations. Integration is a key aspect of Industry 4.0, and the technological requirements had been discussed in this chapter. These requirements are the technological backbone of global networks, bandwidth and processing hubs to connect digital entities. The main focus is on a machine-to-machine communication, connecting machines with each other, combined with deep learning procedures, will increase speed and efficiency for organizations. This new development to process information over distances is the key result of a new digital infrastructure with high performance networks and broad bandwidth. This digital network is the backbone of digitalization and will enable further growth for digitalization of decision-making. Using latest technology, new decision processes distinguishes an organization from competition, e.g. using collaborative platforms, or crowdsourcing improves the quality of the decision process.[105] A further technological aspect is the usage of big data, defined as smart data. Today, every second data are produced in manifold ways. Value creation starts, when it's possible to use these data in a business-driven attitude. Then these data are becoming smart data, because these will support a business model and will create value for an organization. The analysis and utilization of data is today possible, with enhanced technological tools in the area of analytics. The idea to draw conclusions out of these data is the next step of the development and created the field of predictive analytics. Combining new technology with physical systems, new technological opportunities will arise, smart machines and robots will deliver services, we were never thinking about. The setup of

[105] Chiu C. 2014. What can crowdsourcing do for decision support? Decision Support Systems 65 (2014). Elsevier. Pp. 40 - 49

completely automated factories without humans is reality today, further robot advisors take over manual tasks and cobots are focused on working in a collaborative approach with humans.

Organization as further influencing factor for digitalization of decision-making with mentioned changes in the environment affects traditional organizational structures. The current trend is ongoing and traditional structures are changing or disappearing, because of new technological possibilities and market driven developments. These developments, e.g. broader spread of a global organization in a matrix organization or temporary freelancer for dedicated projects, are influencing organizational structures. Organizational hierarchies won't have a clear set up as in the past and borders of organizations blur respectively or moving toward a process driven collaboration in organizations.[106] The huge advantage of digital structures is a simultaneous documentation of the process, which creates transparency in the organization. This is an important aspect of corporate governance and regulatory requirements. As mentioned, Simon understands decisions in organizations as a matter of compromise, new organizational structures will change it. Requirements for a higher speed in decision-making with technological possibilities will intensify this trend on a higher level of transparency.

1.2.4. Impact of Digitalization of Decision-Making

The five areas of digitalization, smart data, automation, integration, digital customer access and new business models, as described above, are relevant elements for digitalization of decision-making. The setup of these key items in organizations is a main driver for decision-making performance.

Digitalization and more in detail, data are becoming more and more important in the periphery of decision-making. In the field of decision-making, using data is the most important development. As explained above, there are more aspects of decision-making, e.g. experience, heuristics and „gut feelings". Today, in a highly competitive environment, with the need for fast and high-quality decisions, humans are overstrained to cope with these complex requirements. Automated or even autonomous data usage provides a competitive advantage for organizations to succeed in their process of decision-making.[107] From the author's view it is quite important to involve and provide the entire organization for this new paradigm of decision-making. Every single department needs to adopt to this development in the strategic journey of a digital transformation. An important step for organizations is, to convert data into analytics for usage in applications or even for new business models. „Analytics is the process of collecting, processing, and analyzing data to generate insights that help you improve the way you do business. In most cases, it involves software-based analysis using algorithms."[108]

Today there are many tools and techniques for analyzing data on the market, improving the ability to create value out of these data. For these analytics and finally for the concept of decision-making in an organization, different types of analytics are relevant to mention, as in table 1-5.

[106] Picot A. & Reichwald R. & Wigand R. 2001. Die grenzenlose Unternehmung. München. Gabler Verlag
[107] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 37
[108] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. P. 101

Types of Analytics - Explanation *Table 1-5*

Types	Explanation
Text	= text mining: process of extracting value from large quantities of unstructured text data, e.g. text-based data from documents, emails…
Sentiment	= opinion mining: extract subjective opinion from text, video and audio.
Image & video	Extracting data from images, e.g. photos, medical images or graphics.
Video	This is the process of information from video footage. This includes everything that image analytics can do; it measures and track behavior.
Voice	Process of extracting information from audio recordings. Simple analytics of words and phrases, the emotional content of a conversation.
Data mining	It's often a general description of any form of large-scale data processing. In detail, data mining is an analytic process to explore data and looking for commercial relevant insights, patterns or relationships between variables that can improve performance.
Business experiments	Experiential design is a technique for testing the validity of a hypothesis or a new approach. Quite often it's a comparison of two conditions.
Visual	Very simple way of analytics, to create a visual graph and analyze the spot pattern or trends.
Correlation & regression analysis	Statistical tools to analyze data. Correlation analysis determines the strongness of a relationship between two variables. Regression analysis analyze the relationship of variables and plots the course of relationship.
Scenario analysis	To project a variety of possible future events or scenarios by considering alternative possible outcomes. Esp. in condition of uncertain decisions.
Forecasting	Data are measured consistently at particular times to plot changes.
Monte Carlo simulation	Problem solving and risk assessment technique that approximates the probability and the risk of certain outcomes using computer simulations.
Linear Programming	Linear optimization: the method to identify the best outcome based on the set of constraints by using a linear model.
Cohort analysis	Subset of behavioral analytics, which allows to study the behavior of a group over time.
Factor analysis	Collection of statistical techniques that are used for data reduction and structure detection.
Neural network	Computer program based on the human brain and can process a mass of data to identify patterns in a similar way a human brain is working.
Meta data	The idea is to find patterns and relationships among literature and studies.

(Author's construction, based on Marr[109])

[109] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 103

Depending on the mentioned types of analytics, the decision-making process with an expected quality, should have an improved basis for decision, because in the past, lot of these opportunities weren't possible. Only the editing of structured data had been possible, today new alternatives to process and evaluate semi-structured and unstructured data are established and opens up new possibilities of data analysis for improved decision-making.

Advanced analytics are quite important for the new way of analysis, like machine learning, deep leering and cognitive computing. For machine learning and deep learning, the process of feeding data into machines, which then decide the best path of action without any human interaction in the decision process is a technology which is available today. Technically, these computers are not exact programmed for one special task to solve, these are able to change and improve their algorithms by themselves in a designed learning curve. Hence there is an improvement of the decisions over time, because more data are used for the algorithmic model and the following decisions are improved autonomous due to a digital learning curve. Contradictory, cognitive computing is following another path, by simulating the human brain, which is close to neural networks. The analysis of the human brain and the functions of it will be combined with computer science. Therefore, these human brain functions will be programmed into a computer model to simulate these human functions in a digital setup.[110] As an example the IBM project Watson is a combination of deep learning algorithms and neural networks to process information. Based on intensive data processing of the system, the autonomous learning curve of it generates a higher quality of the system's decision as a permanent process.[111]

Decision Support Systems are well known systems which facilitate decision-making for human beings, but the last step, to execute the decision, will remain in human hands. As Simon states in 1965, that encouraging results from early studies of this kind raised hopes that it's might be possible to use computer programming languages formally as well as informally to construct theories of organizational decision-making, and further to test those theories by simulating the decision process on a computer. Computer programs try to simulate important aspects of the human behavior in situations. These decisions that have been simulated had been in 1965 simple ones. There was a considerable specific knowledge on how human beings accomplish complex cognitive tasks and reasons for optimism, that this body of knowledge will increase rapidly, in the digital computer language.[112] Simon contributed in the 1960ies to the idea of digitalization of decision-making, first approaches took place to move decisions from human beings to machines. Putting this remark into the context of today, driven by technological progress, much more possibilities of digitalization are given today. In an early stage, constructing of models - such as expert systems - describes the decision-making process in common. In a developed stage, people construct logical rules that make decisions. Sophisticated stage of decision-making will construct simulation models, such as econometric models in finance or climate models, to

[110] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. P. 114

[111] High R., 2012. The Era of Cognitive Systems: An Inside Look at IBM Watson and How it Works. 12-2012. http://johncreid.com/wp-content/uploads/2014/12/The-Era-of-Cognitive-Systems-An-Inside-Look-at-IBM-Watson-and-How-it-Works_.pdf. Pp. 7. Accessed: 06.03.2018

[112] Herbert A. Simon. 03-1965. Administrative Decision-making. Source: Public Administration Review, Vol. 25, No. 1, Twenty-Fifth Anniversary Issue (Mar., 1965). Published by Wiley on behalf of the American Society for Public Administration. Pp. 31-37. Accessed: 30.10.2017

test assumptions. These models typically use system models to represent alternative scenarios. The power of these models is, that they can be used to test the effects of different assumptions. The quality and utility of the models depend on the quality of the scenarios and mental simulations. A limitation of these models is, that they represent decisions only in terms of quantitative factors, ignoring the qualitative context which are driven by unconscious emotions and identity-based beliefs.[113]

The trend of predictive analytics is one aspect of preparing data in a forecasting model for decision-making. Predictive analytics is a part of advanced analytics which is used to make estimation about unknown future events. It's using many techniques from data mining, statistics, modeling, machine learning and artificial intelligence to analyze current data, to make estimations about the future.[114] Prediction for organizations are important, because in a complex world with increased competition, moving before your competitor moves is quite important, hence prediction empowers organizations with a new form of competitive advantage. Focusing on details, predictive analytics have a different approach, compared to forecasting. Forecasting collects data on a high level, but predicative analytics is on a deeper level of data accuracy. As an example, forecasting is estimating the revenue for the next months of an organization. Predictive analytics is estimating the revenue on customer and product level. The basis of this prediction is a huge data set. Databases in an organization are manifold, from typical ERP systems to CRM systems and focusing on production systems. This important development is driven by technological progress and the related setup of decision models. Using the speed of response, corrective actions are possible almost online and far superior compared to human decision speed.[115]

Artificial intelligence is a huge buzz word since decades in business and science, and the fear of artificial intelligence in a human society is existent. The fear of losing control and moving this control to machines is evident and pictured in many Hollywood blockbusters, but far from reality. Today machines are able to operate in a described environment, more efficient than humans. Machines only uses their model of activity, which is very limited compared to humans. Nevertheless, these boundaries are moved day by day toward the edge of technology. An early definition of artificial intelligence was made by John McCarthy as „the science and engineering of making intelligent machines"[116]. The view was, machines act as intelligent as human beings and machine behavior is simulating intelligence. Artificial intelligence has a long tradition in computer science, but never had a break through with its technology in business. Starting these days with huge calculating power and sophisticated models, artificial intelligence is becoming more advanced and suitable for business applications. The idea of cognitive computing, which means cognitive science (the study of the human brain) and computer science will be combined. The approach of simulating human thoughts and mimic how a brain is working, should bring artificial intelligence to the expected success. Cognitive computing is underpinned by machine learning and deep

[113] David H. Jonassen. 04-2012. Designing for decision-making. Source: Educational Technology Research and Development, Vol. 60, No. 2 (April 2012). Published by: Springer Stable URL: http://www.jstor.org/stable/41488586 . Pp. 31-37. Accessed: 30.10.2017

[114] Definition of predictive analytics. https://www.predictiveanalyticstoday.com/what-is-predictive-analytics/ Accessed: 14.02.2018

[115] Seung-Jun Shin S-J & Woo J & Rachuria S., 2014. Predictive analytics model for power consumption in manufacturing. 21st CIRP Conference on Life Cycle Engineering. Procedia CIRP 15 (2014). Published by Elsevier B.V.

[116] McCarthy J., 1956. Definition of Artificial Intelligence. Conference at Dartmouth college. https://www.artificial-solutions.com/blog/homage-to-john-mccarthy-the-father-of-artificial-intelligence. Pp. 153 - 158. Accessed: 14.02.2018

learning technology, which enables computers to learn autonomously from data, without external input of knowledge. The knowledge is created inside the model.[117]

Blockchain technology is a digital, decentralized, public ledger transaction. Blockchain differs from other opportunities with a validation of every single transaction. Often referred reaching "consensus" on the transaction, removes the need for intermediaries and enables direct peer-to-peer transactions. The process is promising, because it builds trust, minimizes value leakage and creates a playing field for commerce to thrive. Validated transactions are posted to an immutable ledger that is shared between partners. Everyone has a copy of the transaction log, so any change in any ledger will make it inconsistent with others. This process makes it practically impossible to tamper with the log, because everyone can see everything. Blockchains also provide transparency to all partners. Finally, "smart contracts…are the simplest form of decentralized automation."[118]

Decision-making had been always based on data. In the digital era the quality and the amount of data increased. These days, organizations collect all possible data, but don't have any idea how to work with these data. A clear data strategy is necessary to use these data for business decisions. Bernard Marr touched this topic, of using data to make better decisions, because the major goal of an organization is to make better decisions compared to competition. This is a very general view, because based on the data set, managers want to understand the market, trends in product development, transparency in production flows to generate efficiency and finally increase profit. The questions had been the same for decades, but the quality of analytics changed tremendously, because big data and the corresponding tools for data analytics will deliver results on a more sophisticated quality level for organizations and their executives. [119]

Industrial organizations with manufacturing, machines, vehicles or tools have to focus on the smart aspect of the development in this area. These features are connected, data enabled and constantly reporting their status to other machines. Machine data may include any data, from IT machines to sensors or meters and also GPS devices. Using these data, organizations will gain real-time insights in their operation processes. The goal, to increase efficiency of manufacturing processes by monitoring the performance, steering actions for cost optimization. Supply chain will be optimized by using data, mainly GPS, traffic or weather data. If, for example, GPS data are tracked by a company, the visibility of a company fleet is given and inefficiencies will disappear. In a more service focused environment, automation and data traceability will gain further advantages.[120]

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[117] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 6

[118] Najmi A., 01-2018. Why Your Supply Chain Needs Blockchain: Understanding the Technology and Its Link to Supply Chain Networks. http://data-informed.com/why-your-supply-chain-needs-blockchain-understanding-the-technology-and-its-link-to-supply-chain-networks/?utm_campaign=Monthly%20Newsletter&utm_source=hs_email&utm_medium=email&utm_content=60388934&_hsenc=p2ANqtz-_EG-HgTRvBLUxVdVfPb7jOGNgaAVTqvBD5KmhvTA8hW28hVaIWgOtueN8jQATarRvGE8ZCLzI8vq-6yFPmCgoQnBTcqA&_hsmi=60388934. Accessed: 08.02.2018

[119] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. Pp. 21

[120] Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan. P. 26

1.3. Theoretical Analysis of Supply Chain Management

Supply chain management is a growing discipline in economical science and practical business world, driven by efficiency efforts of organizations to survive in a competitive environment. A trend of organizations to focus on their core activities, and to spread their product portfolios including services, supply chain management creates opportunities to succeed. Influencing factors like complexity, response time, organizational requirements or even technological developments have to be managed. To analyze complexity in the context to supply chain management, the trend of globalization is the most obvious one. Management of a global sales and distribution networks is a challenge which should be covered by a supply chain management concept. Market requirements, the competitive situation and new product features are relevant drivers for new approaches in collaboration between supply chain management and digitalization. Shorter response time in the market drives supply chain to a higher degree of automation. A proper supply chain management is mandatory, because shorter product life cycles will tolerate less failures. Nevertheless, the necessity for efficiency is not limited to one single global organization, the scope is moving toward an end to end value chain with all related parties. Supply chain management in combination with digitalization will have an impact on these new cross-organizational structures.[121] Finally, advanced technological progress and development of new technological applications have created new opportunities for organizations or value chains to reach a more competitive position in their industry. As an example, the technology of blockchain with all related transactions is one driver in the supply chain environment to gain efficiency.

1.3.1. History of Supply Chain Management

In a historical context the definition of logistics and supply chain management is worth to examine. The term supply chain management appeared the first time in the late 80ies of the last century and got more important with an enhanced theoretical foundation in the 90ies. Before the definition of "supply chain management" the terms "logistics" or "operations management" were used in theory and practice.[122]
The arose of supply chain management were driven by the necessity for efficiency due to increased competition between organizations. An idea to find a competitive advantage beside common strategies, as quality management, information technology or business process reengineering, the most successful ones focused on supply chain management. The idea was to accelerate transactions and information speed including strengthen of channel loyalties.[123] From a historical view, supply chain management was an approach to use enterprise management tools to connect with suppliers and customers. The aim to reduce costs by improving the process quality went hand in hand. The mentioned tools had been enterprise resource planning (ERP), total quality management (TQM) and business process reengineering (BPR) for lean manufacturing and improved distribution functions.

[121] Pfohl H.-C., 2010. Logistiksysteme: Betriebswirtschaftlich Grundlagen. 8. Auflage. Springer Verlag. Berlin. Pp. 12
[122] Hugos M., 2003. Essentials of Supply Chain Management. John Wiley & Sons, Inc., Hoboken, New Jersey. P. 2
[123] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 1

A second aspect, organizations divest from different functions to reduce costs or to increase competitiveness, a collaboration with supply chain partners were necessary to deliver the full range of the own product portfolio. Moreover, a shrunken product life cycle stimulated this development over industries. TQM combined with Supply Chain Management accelerated the scope of decreasing cost in the supply chain as well as improvement of quality and security.[124] A third aspect, the global trade of goods has opened old boundaries and gave the opportunity for new markets and new forms of competition. Internet technology and the structure of international logistics enabled organizations to distribute their product offerings to the whole world without limitations. A fourth aspect was the requirement for organizations to deliver efficient and flexible to customers. The necessity is driven by changed consumer behavior and the expectation for a more tailored, high quality and best price, immediate delivered product offer, in relation to Kreutzer & Land.[125] To reach these requirements, a collaboration with specialized partners is a precondition for organizations is today's fast changing business world. Finally, technological progress enabled organizations to fulfill these required connections between business partners and enabled stable distribution channels. The exchange of data via Internet was a vital aspect of a stable supply chain. Further tools like electronic data interchange (EDI) or blockchain technology is driving this development even faster.[126]

"Historically, synchronizing the supply chain has always occupied a central position in the management of the enterprise, linking marketing and sales strategies with manufacturing, inventory, and service function. As far back as the beginning of the twentieth century, economists considered the activities associated with effectively managing business channels to be the crucial mechanism by which goods and services were exchanged through the economic system." [127] This traditional view is defined by Levy and Grewal with their article about "Supply Chain Management in a Networked Economy", understanding supply chain as an automatic replenishment system, also called vendor managed inventory.[128] This aged approach in today completely different and more focused on value creation than material flows.

[124] Xiao R. & Cai Z. & Zhang X., 2009. An optimization approach to cycle quality network chain based on improved SCOR model. Progress in Natural Science, 2009. ScienceDirect. Pp. 881-890 Accessed: 17.10.2019
[125] Kreutzer R. & Land KH. 2015. Digital Darwinism – Branding and Business Models in Jeopardy. Berlin. Springer Verlag, P. 46
[126] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 3
[127] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 5
[128] Levy M., Grewal D. 2000. Supply Chain Management in a Networked Economy. Journal of Retailing. Vol. 76 (4) P. 416

Supply Chain Management Stages in Historical Development over Time *Table 1-6*

SCM Stages Over Time	Stage Definition	Management Focus	Organizational Design
Up to 1960s (Stage 1)	Warehousing and Transportation	Operations performance Support for sales/marketing Warehousing Inventory control Transportation efficiencies	Decentralized logistic functions Weak internal linkages between logistics functions Little logistics management authority
1960 to 1980 (Stage 2)	Total Cost Management	Logistics centralization Total cost management Optimizing operations Customer service Logistics as a competitive advantage	Centralized logistics functions Growing power of logistics management authority Application of computer
1980 to 1990 (Stage 3)	Integrated Logistics Management	Logistics planning Supply chain strategies Integration with enterprise functions Integration with channel operations functions	Expansion of logistics functions Supply chain planning Support for TQM Expansion of logistics management functions
1990 to 2000 (Stage 4)	Supply Chain Management	Strategic view of supply chain Use of extranet technologies Growth of co-evolutionary channel alliances Collaboration to leverage channel competencies	Trading partner network Virtual organization Market co-evolution Benchmarking and reengineering Supply chain TQM metrics
From 2000 on (Stage 5)	e-Supply Chain Management	Application of the Internet to the supply chain management concept Low-cost instantaneous sharing of all databases e-Information Supply chain management synchronization	Networked, multi-enterprise supply chain .coms, e-trailers, and market exchanges Organizational agility and scalability

(Source: Author's construction based on Ross D., 2003)[129]

[129] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 6

Referring to table 1-6 “Supply Chain Management Stages in Historical Development Over Time” the development of the supply chain function is explained by Ross in 5 stages. Reflecting the economic situation of the first stage, which was starting before the 60ies of the last century, this era had long process and delivery times, less global competition and a market environment pictured by mass production and mass distribution. Summing up, in this time logistics or supply chain management was not a competitive advantage including a significant contribution to profit optimization for organizations. It was simply an intermediary function engaged with inventory management and delivery. While the second stage of supply chain management, between the 60ies and 80ies of the last century, the function developed. The function of supply chain management evolved in two critical points. First, the focus of organizations moved to centralization of logistics functions to a single management system. Second, the scope on centralization should result into a reduction of total costs of logistics. Considering the economic situation of the 1970ies with increasing carrying costs (due to the energy crisis), increasing delivery response to customers and fragmentation of the distribution channel by marketing, pricing and promotions, drove mentioned developments. During the 80ies of the last century, the third stage of supply chain management arose and focused quite strong on total cost of logistics. Two main focal points had been in the center of activities, competition and quality management. First, an increased competition occurred by globalization of organizations and their distribution network, driven with activities in productivity, quality and profitability. A second focus, to reach competitive advantage, was driven by quality management with the concepts of JIT and TQM. Following, in stage 4, in the 90ies, the term supply chain management namely appeared. The idea was to expand the function of logistics and supply channel management into an integrated function of supply chain management. Driven by the acceleration of globalization, the increasing customer power with higher levels of service, supplier agility, outsourcing and new possibilities of information technology defined the structure of supply chain management. These were the days, when logistics moved to an integrated supply chain management concept. Designing the SCOR model (Supply Chain Operations Reference model) is illustrating the differences between stage 3 and 4 of the development, with organizational cross border connections. Stage 5, beginning with the new millennium, transferred the supply chain concept to an e-supply chain concept, based on digital features in a connected world. Supply chain management evolved to a powerful strategic function to create customer value propositions by external collaboration of channel partnerships. Organizations began first to integrate their internal supply chain functions, then the integration across trading partners, like transportation, inventories and forecasting occurred. Finally, the highest level would be to achieve a “virtual organization” by using the power of digital connection and integration.[130] Latest developments of e-supply chain management went into a deep collaboration cross-organizational with adequate security enhancements. One important technology for supply chain management is currently blockchain technology, with an enormous level of security and efficiency.

[130] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 7

1.3.2. Definition of Supply Chain Management

Over time, supply chain management developed from an operational function to a strategic concept. The definition of supply chain management is important for this dissertation and defined as follows.

"A supply chain is the alignment of firms that bring products or services to market"[131]

"A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves."[132]

"A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers."[133]

"Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served."[134]

"SCM is about breaking down walls between companies which traditionally looked at SCM only as a way to cut costs…No matter how complex the enterprise is, it must operate in an integrated manner."[135]

"The digital supply chain is characterized by the strategic and operative exchange of information between suppliers (financial, production, design, research, and/or competition) to enhance communication between actors in the chain. In general, interorganizational coordination is achieved by means of electronic links between information systems…"[136]

The definition from Yoo et al (2010) that digital technologies have three important characteristics like reprogrammability, homogenization of data and self-referential nature of digital technology has to be extended by the scope on supply chain management which should also include management of decentralized and autonomous processes.[137]

As explained in the historical part of this chapter, there is a difference between the concept of supply chain management and the traditional concept of logistics. Logistics is an early view on the topic and in general refers to activities within the boundaries of an organization and supply chain management refers

[131] Lambert D. M. & Stock J. R. & Ellram L.M., 1998. Fundamentals of Logistics Management. Irwin/McGraw-Hill Boston, MA. Chapter 14
[132] Chopra S. & Meindl P., 2001. Supply Chain Management: Strategy, Planning, and Operations, Prentice-Hall, Inc. Upper Saddle River, NJ. Chapter 1
[133] Ganeshan R. & Harrison T.P., 1995. An Introduction to Supply Chain Management. Department of Management Sciences and Information Systems, Penn State University, University Park, PA. http://silmaril.smeal.psu.edu/ supply_chain_intro.html Accessed: 20.12.2019
[134] Hugos M., 2003. Essentials of Supply Chain Management. John Wiley & Sons, Hoboken, New Jersey. Pp. 2
[135] Irfan D. & Xiaofei X. & Chin D. S. 2008. A SCOR Reference Model of the Supply Chain Management System in an Enterprise. The International Arab Journal of Information Technology, Vol. 5, No. 3, July 2008, P. 288
[136] Korpela K. & Hallikas J. & Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666. Pp. 4183. Accessed: 15.10.2019
[137] Junge A.L., 2019. Digital Transformation Technologies as an Enabler for Sustainable Logistics and Supply Chain Processes – an Exploratory Framework. Brazilian Journal of Operations & Production Management 16. Pp. 462-472. P. 463

to a network of organizations which collaborate together and coordinate their actions to deliver products or services to market and customers. Furthermore, traditional logistics focuses its attention on activities like procurement, distribution, maintenance, and finally inventory management. Supply chain management considers all traditional logistics content, but includes activities as marketing, new product development, finance, and customer services. In this dedicated wider view of supply chain management thinking, these additional activities are today seen as part of the task necessary to fulfill customer requests. Consequently, supply chain management recognizes the supply chain including all related organizations in it, as a single unit. This creates a concept understanding and managing all activities needed to coordinate the flow of products and services to serve customers. This system provides a framework in which business requirements are perfectly covered that otherwise would seem to be in conflict with each other. Supply chain management is integrated planning and steering of goods, information and financials along the entire value chain from raw material supplier to the consumer. The goal is to optimize customer centricity, synchronizing of supply, flexibility and tailored production along the value chain.[138] Understanding this key definition of supply chain management as the link between suppliers, intermediaries, logistic organizations and customers. An important aspect to reach the defined goals, is to manage the interfaces between all related partners.[139]

The linear total cost function of supply chain management is described as follows in mathematical terms:[140]

$$S = c_{ij}\, x_{ij} + c_{kl}\, x_{kl} + c_{mn}\, x_{mn} + c_{opq}\, x_{opq} \qquad \text{Formula 1-2}$$

c_{ij} - is cost of raw material i at vendor j

x_{ij} - is amount of raw material i purchased from vendor j

c_{kl} - is cost of holding material k at inventory l

x_{kl} - is amount of material k retained at inventory l

c_{mn} - is cost of manufacturing product m at plant n

x_{mn} - is amount of manufacturing product m at plant n

c_{opq} - is cost of transportation material o between node p and q

x_{opq} - is amount of material o transported between node p and q

The relevance of **decision-making in the supply chain function** is significant, because of complexity and uncertainty. An important principle of supply chain management is the reduction of uncertainty in the decision-making process of all related organizations within the supply chain. Therefore, the coordination of management processes in supply chain management requires information exchange

[138] Hellingrath B. & Hegmanns, T. & Maaß, J.-C. & Toth M.; 2007. Prozesse in Logistiknetzwerken – Supply Chain Management. Handbuch Logistik. 3rd edition, Springer Verlag Berlin / Heidelberg. Pp. 459 - 486
[139] Hugos M., 2003. Essentials of Supply Chain Management. John Wiley & Sons, Inc., Hoboken, New Jersey. P. 4
[140] Irfan D. & Xiaofei X. & Chin D. S. 2008. A SCOR Reference Model of the Supply Chain Management System in an Enterprise. The International Arab Journal of Information Technology, Vol. 5, No. 3, July 2008, P. 289

between the participants of the supply chain. The improved availability of digital information in the decision-making units of the supply chain reduces uncertainty, focuses on better control and improved performance. The idea behind, is to provide all supply chain participants with better and more timely information about orders, products and special needs. The support of all members, to shorten work cycles by removing obstacles and to synchronize lead times and capacities between the levels of the supply chain, is a key task.[141]

The SCOR model, as shown is figure 1-4 „SCOR Model" describes the entire supply chain process, and SCOR (Supply Chain Operations Reverence Model) is relevant in management science and practice.

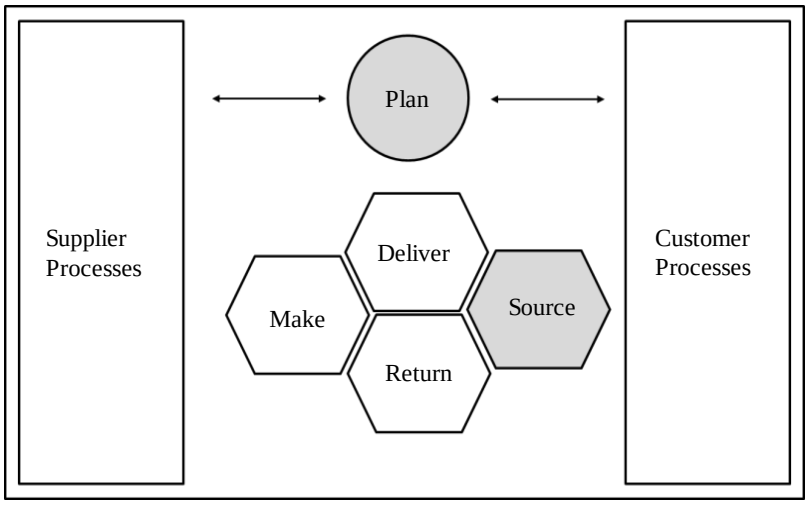

Figure 1-4 **SCOR Model**

(Author's construction, based on Bolstorff P. & Rosenbaum R. 2007)

The SCOR model is described with its 4 major components (by Supply Chain Council):

- **Performance**: Standard metrics to describe process performance and define strategic goals
- **Processes**: Standard description of management processes and process relationships
- **Best Practice**: Management practices that produce significant process improvements
- **People**: Standard definition for skills required to perform supply chain processes

The SCOR model is designed for all activities of suppliers, customers, material flows and market interactions based on 5 basic transactions: plan, source, make, deliver and return. The detailed description is displayed in table 1-7 "SCOR Elements".[142]

[141] Irfan D. & Xiaofei X. & Chin D. S. 2008. A SCOR Reference Model of the Supply Chain Management System in an Enterprise. The International Arab Journal of Information Technology, Vol. 5, No. 3, July 2008, P. 289
[142] Georgise F.B. & Thoben K.-D. & Seifert M., 03-2012. Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda. International Journal of Business and Management. Vol. 7, No. 6, March 2012. P. 4. Accessed: 17.08.2019

SCOR Elements *Table 1-7*

SCOR Element	Definition
Plan	Processes which include gathering customer requirements, collecting information on available resources, balancing requirements and resources to determine planned capabilities and resource gaps
Source	Processes which describe the ordering and receipt of goods and services
Make	Processes which describe activities related to the conversion of materials or creation of the content for services
Deliver	Processes which describe the activities related to creation, maintenance and fulfillment of customer orders
Return	Processes which describe the activities related to the reverse flow of goods or services back from the customer

(author's construction, related to Georgise et al; 2012)

1.3.3. Influencing Factors of Supply Chain Management

To act in a competitive market, decision-making in supply chain management is a key factor for success. Mainly the speed of response to customer activities is important, because competition is just one click away. It is not only the response time, even the quality of the reaction itself, compared to the competitor's performance is a success factor. As an example, if an organization is running out of stock, the supply chain needs a real-time reaction to satisfy the customer. The communication to the customer may occur even in real-time, because of a digital supply chain, a delivery time is estimated and transferred to the customer.[143] Reflecting in this context digitalization of the supply chain, influencing factors are important elements for digitalization. What are the drivers for a development from an operational logistics function to a supply chain function. Influencing factors are relevant, determining the development of a situation or technology.[144] Influencing factors are important for digitalization and exhibit similar effects compared to supply chain management. Table 1-8 "Influencing Factors of supply chain management" exhibits influencing factors of supply chain management and a need for analysis.

[143] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 25

[144] Nazarko J. et al. 2016. Structural Analysis as an Instrument for Identification of Critical Drivers of Technology Development. Proceedings of 7th International Conference on Engineering, Project, and Production Management (EPPM2016). Poland. Pp. 474 - 481

Influencing Factors of Supply Chain Management *Table 1-8*

Influencing Factor	**Details**
Complexity	Globalization Supply chain disruptions New markets (competition, supplier, customer) Revenue increase
Response time (by synchronization of supply chain)	Shorter decision paths Quick time to market High innovation rate Shorter product life cycle Working capital reduction
Technology	Increased calculation performance Integration (machine-to-machine communication) Usage of big data Automation of processes
Organization	Increasing size of organizations Global spread and management of organizations Organizational and process transparency Cost & working capital reductions in the process

(Author's construction)

Complexity: One important driver for development of supply chain management is globalization. The definition of globalization, as discussed before is the international integration from the interchange of views, products, ideas and other aspects of culture.[145] As discussed before, both trends moved hand in hand, globalization drove the development of supply chain management to a key role in organizations and management. Further, the open markets in Eastern Europe and Asia changed the landscape of organizations and their spread in distribution significantly. These new activities in a global marketplace redirected the role of logistics and distribution to a strategic role in organizations. As a global approach, the idea of value chains is vital for a successful market penetration. Different strategies were developed to be competitive, like building effective channel alliances or global collaboration, globalizing internet content, responding to national governments on global bodies, e.g. WTO.[146] Supply chain integration is a collaborative inter- or intra-organizational management on strategic, tactical or operational processes

[145] Albrow M. & King E.,1990. Globalization, Knowledge and Society. London: SAGE
[146] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 46

to achieve efficient flows of products, services, or information to maximize customer value.[147] A very apparent influencing factor of a supply chain are disruptions caused on various circumstances. Risks of a supply chain and their drivers are displayed in table 1-9 "Supply Chain Management Risks". These significant risks in supply chain management leads to a need for a robust.

Supply Chain Management Risks *Table 1-9*

Category of Risk	**Drivers of Risk**
Disruptions	Natural disaster Labor dispute Supplier bankruptcy War and terrorism Dependency on a single source of supply Capacity of alternative suppliers
Delays	High capacity utilization Inflexibility Poor quality or yield Excessive handling due to border crossing or to change transportation
Systems	Information infrastructure breakdown System integration or extensive systems networking E-commerce
Forecast	Inaccurate forecasts due to long lead times etc. Bullwhip effect or information distortion
Intellectual property	Vertical integration of supply chain Global outsourcing and markets
Procurement	Exchange rate risk Percentage of a key component or raw material produced by a single source Industrywide capacity utilization Long-term vs. short-term contracts
Receivables	Number of customers Financial strength of customers
Inventory	Rate of product obsolescence Inventory holding costs Product value Demand and supply uncertainty
Capacity	Cost of capacity Capacity flexibility

(Author's construction based on Chopra/Sodi) [148]

[147] De Vass T. & Shee H. & Miah S., 2018. The effect of "Internet of Things" on supply chain integration and performance: An organizational capability perspective. Australasian Journal of Information Systems 2018, Vol. 22. P. 4
[148] Chopra S. & Sodhi M.S. 2004. Managing Risk to Avoid Supply-Chain Breakdown. MIT Sloan Management Review. Fall 2004. P. 54

Avoiding the risks of table 1-9, a bundle of actions is necessary, and mainly driven by the improvement of data flow for better decision-making of participants. A detailed description of actions is given in the paper "Managing Risk to Avoid Supply-Chain Breakdown" from Chopra and Sodhi.[149] A further important driver of complexity is the view on new markets in correlation to supply chain management. Globalization drove economies of scale for efficiency gains, and the integration of a supply chain within the overall business strategy should ensure further competitive advantages.[150] This is essential, because the role of supply chain management changed competition, supplier and customer behavior. The statement, competition is just one click away, is essential for an effective strategic position in the market.

An important influencing factor for supply chain management is **response time**. The idea to optimize response time for an improved strategic position in the market, possesses supply chain management as an answer. The precondition for an improved response time is the synchronization of the supply chain. Technological features are given, as established EDI with limitations in technology for channel trading partners.[151] A known effect, the bullwhip effect, is driven by less coordinated supply chains, caused by weak demand forecasts, order batching, price fluctuation or rationing of goods.[152] The effect of synchronization in the supply chain will affect the working capital of participants, with a reduction of inventory. Exchange of information on a real-time level, will enable the supply chain partners to manage their stock transparent, with reduced restocking and lead times. Even the financial transaction flow in supply chain management will have an effect of working capital, in the positions accounts receivables and accounts payables. Defined payment terms or an automatic credit memo procedure will improve these transactions in supply chain management.

"The capture, compilation, and communication of information could provide companies with radically new avenues to generate wealth by reaching previously inaccessible markets, providing revolutionary mediums for the transfer of goods and services, enabling new ways to capture customer loyalty, and enabling innovative companies to do things they never dreamt they could do"[153] The main driver for these developments and efficiency gains is **technology**. In chapter "1.2.2. Definition of Digitalization" the aspect of technological progress is explained in detail, and the main effect is reflected by the development of processing power of computer chips. This development permitted new applications, hand in hand with an increasing infrastructure to connect the participants of the supply chain, for a deeper collaboration. Internet of Things enables objects and devices to connect with the Internet for

[149] Chopra S. & Sodhi M.S. 2004. Managing Risk to Avoid Supply-Chain Breakdown. MIT Sloan Management Review. Fall 2004. Pp. 53 - 61
[150] Awad H., Nassar M.O. 2009. Supply Chain Integration: Definition and Challenges. Manuscript of 28.12.2009
[151] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 27
[152] Lee H.L. & Padmanabhan V. & Whang S. 1997. The Bullwhip Effect in Supply Chains. Sloan Management Review. Spring 1997. Pp. 93 - 101
[153] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 44

communication, based on embedded objects like sensors or software.[154] Technology in scope of supply chain management creates transparency of processes and assets.[155]

Digital Transformation Technologies and Capabilities in Supply Chain Management *Table 1-10*

Digital Transformation Technologies	**Capabilities**
Information and communication technologies	Integration
Auto-identification technologies	
Cloud systems	Visibility
Cyber-physical-systems	
Analytics	Real-time
Blockchain	
Automation technologies	Decentralization
Virtual and augmented reality	
Additive manufacturing	Automation

(Author's construction, according to Junge)[156]

Digital transformation technologies as mentioned in table 1-10 are an enabler for digitalization of decision-making features in supply chain management. Latest technologies like cloud systems, cyber-physical-systems or additive manufacturing will create new possibilities for supply chain management from a technological perspective. Blockchain technology will increase the security aspect, analytics, virtual or augmented reality will enable a deeper level of collaboration between supply chain partners. The change of competitive conditions, triggered a change in organizational structures. The underlying technological progress accelerated this development. Even the effect of globalization and economic growth created the necessity to adapt to the size of organizations. The necessary response created pressure on organizations, to deliver transparent and quick decisions, internally and cross-border in supply chain management. The increased competition and the opportunities of technological progress opened the possibility for cost and working capital reductions for all members. Finally, it is the willingness of trading partners to adapt the organization for leveraging the advantages which are possible now. A lack of common values, behavior and beliefs in the supply chain will drain the high level of trust and collaboration, which is necessary for a successful supply chain.[157]

[154] De Vass T., Shee H., Miah S., 2018. The effect of "Internet of Things" on supply chain integration and performance: An organizational capability perspective. Australasian Journal of Information Systems 2018, Vol. 22. Pp. 1
[155] Junge A.L., 2019. Digital Transformation Technologies as an Enabler for Sustainable Logistics and Supply Chain Processes – an Exploratory Framework. Brazilian Journal of Operations & Production Management 16. Pp. 462-472. P. 464
[156] Junge A.L., 2018. Prospects of Digital Transformation Technologies (DTT) for Sustainable Logistics and Supply Chain Processes in Manufacturing. 2018 POMS International Conference in Rio, Proceedings in Business and Economies Series, Springer International Publishing
[157] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 31

1.3.4. Impact of Digitalization of Supply Chain Management

"The industry 4.0 is transforming the value chain networks…. The industry 4.0 is an ample concept, which also involves e-supply chain applications to facilitate the flow of the smart products."[158] Digitalization of supply chain management is essential for success. Typical effects in the supply chain, as described above, can be managed by digitalization of the entire process.[159]

Cloud computing enables a completely transformed production, and isolated production units merge into a fully integrated, automated, optimized, high-efficiency production process, driving the change in relationships between manufacturers, suppliers and customers.[160] "Internet of Things" is closing the gap between the digital and physical world by synchronizing the digital information flow with the physical goods flow for a better supply chain integration. "Internet of Things" will enable to communicate within the entire supply chain by embedded technology in objects which provide sensing, networking and processing.[161] The idea of supply chain digitalization is, to overcome the risks and obstacles of a traditional supply chain management setup. „Technologies help to increase the agility, adaptability and alignment of companies cooperating in a network of value chains (supply chains) in order to gain competitive advantage."[162]

Smart Data: Data are the foundation of supply chain management and the basis for a transparent collaboration between participants. Structure of data management, e.g. blockchain technology, enables an efficient and highly responsive workflow between partners. The need for data exchange in a supply chain is critical, and the challenge is to overcome a traditional burden in organizations, which means data are often seen as property, but have to be available for decision makers outside the organization in the supply chain. It is a challenge to achieve this level of collaboration, because organizations are reluctant to share critical data.[163]

Automation: The idea of digitalization in the supply chain is successful, because of available data and its possibilities to make automated decisions, e.g. AI or RPA. The idea for automation in supply chain management supports efficiency gains for the organization. Automation within the supply chain management differs from the general understanding of automation. Reflecting Industry 4.0 concept, as an umbrella term for various industrial developments like cyber-physical-systems (CPS), Internet of Things (IoT), Internet of Service (IoS), Robot Process Automation (RPA), Cloud Manufacturing or Augmented Reality, automation tools will support this path. Adopting these new technologies for a more

[158] Muthusami S. & Srinivsan M., 2017. Supply Chain 4.0: Digital Transformation Disruptions and Strategies. Review of Business and Technology Research, Vol 14, No.2. 2017. P. 32
[159] Lee H.L. & Padmanabhan V. & Whang S. 1997. The Bullwhip Effect in Supply Chains. Sloan Management Review. Spring 1997. Pp. 93 - 101
[160] Nagy J., Olah J., et al. 2018. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary. Sustainability 2018, 10, 3491. Accessed: www.mdpi.com/journal/sustainability from 12.02.2020. P.6
[161] De Vass T. & Shee H. & Miah S., 2018. The effect of "Internet of Things" on supply chain integration and performance: An organizational capability perspective. Australasian Journal of Information Systems 2018, Vol. 22. P. 2
[162] Nagy J., Olah J., et al. 2018. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary. Sustainability 2018, 10, 3491. Accessed: www.mdpi.com/journal/sustainability from 12.02.2020. P.7
[163] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. P. 31

intelligent manufacturing process, which includes devices, machines, robots, production modules as a corner stone for efficiency in the supply chain.[164]

Integration: "Connecting the unconnected enables information across the whole supply chain."[165] Machine-to-machine communication is a success factor of digitalization of decision-making. Channel intermediaries are needed to transfer and integrate information across actors or systems, with a shift from manual transactions to digital information flows.[166] The requirement of an independent exchange of information between devices, machines, robots, production modules or products which trigger actions, control or steering, creates an intelligent manufacturing environment and are typical characteristics for Industry 4.0. The term "smart" is a central notion and means independent or autonomous devices, which are able to communicate in real-time and cooperate in a digital environment with connected smart devices.[167]

Digital Customer Access: The role of customers in the supply chain concept changed completely. New possibilities for both parties occurred, on the one hand side, the customer has the next competitive offer just one click away.[168] On the other hand side the sales organization has a high level of transparency through data generation of the customer and is able to track the customer experience.[169] These new opportunities will create new business for customers and suppliers.

New Business Models: Supply chain management affected the structure of business models and changed the setup in different ways. Organizations must develop strategies and business models which will maximize innovation and effectiveness in leveraging digitalization and supply chain integration services in their own business offerings.[170] In combination with digitalization effects on the supply chain concept, new business models emerged and the collaboration of organizations created value in the network.[171]

[164] Pereira A.C. & Romero F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. Proceedings of Manufacturing Engineering Society International Conference 2017, MESIC 2017, Vigo, Spain, P. 1207
[165] Dunbrack L. et al. 03-2016. IoT and Digital Transformation: A Tale of Four Industries. IDC #US41040016, Framingham USA, Accessed: 01.11.2019 P. 12
[166] Korpela K. & Hallikas J. & Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666 Accessed: 15.10.2019 Pp. 4184
[167] Pereira A.C. & Romero F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. Proceedings of Manufacturing Engineering Society International Conference 2017, MESIC 2017, Vigo, Spain, P. 1208
[168] Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida. Pp. 25
[169] Pereira A.C. & Romero F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. Proceedings of Manufacturing Engineering Society International Conference 2017, MESIC 2017, Vigo, Spain, P. 1209
[170] Korpela K. & Hallikas J., Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666 Accessed: 15.10.2019 Pp. 4184
[171] Pereira A.C. & Romero F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. Proceedings of Manufacturing Engineering Society International Conference 2017, MESIC 2017, Vigo, Spain, P. 1209

1.4. Digitalization of Decision-Making in Supply Chain Management

Finally, the theoretical analysis of the scientific fields decision-making, digitalization and supply chain management is processed and developed on a different theoretical extend. Decision-making is a traditional theory, with miscellaneous dimensions in various scientific fields. The antecedent interpretation of decision-making from traditional economists was based on rationality, with the known model of homo oeconomicus and pure rational decision-making. Later, the development of decision making toward other scientific disciplines, like psychology or sociology, created a different view on decision-making theory to more complex dimensions than rationality. Human or social facets of rational decision-making found the way into scientific research.

Digitalization is an emerging scientific discipline, with tremendous theoretical progress and new practical applications. The creation of new theories and ideas in the scientific field of digitalization is increasing permanently. One reason, digitalization is a less isolated scientific discipline, compared to other disciplines and inherent to various scientific disciplines. Today, in manifold scientific areas, digitalization is a key enabler of theoretical development, moving boundaries to a new horizon, based on the above-mentioned digitalization areas of smart data, automation, integration, digital customer access and new business models.

The field of supply chain management is even a relatively new area of scientific research. A consistent development in the recent years, starting from pure logistics, as a more functional or a more technological perspective, evolving to an all-embracing management theory in total, as basis for organizational configuration. The development of supply chain management was mainly supported by the technological progress of digitalization. These new features and applications of digitalization in combination with creation, storing and processing data on ubiquitous platforms was the origin for success of supply chain management in theory and practice. In detail, the measurement of efficiency is given by various KPIs and flexible to chose for the dependency model. The KPIs cost reduction, working capital reduction and turnover growth exhibit the best fit for the application model in supply chain.

The unique combination of all three theories in a model is a sophisticated task, which is not analyzed in depth, yet. Moreover, the scientific discussion of this field is not carried out on a broad scale today. From the author's perspective, the combination of these three theories will built a condensed view on this examined field of research. Digitalization is not a precise research object, but within the relevant applied fields, like decision-making and supply chain management, digitalization will enable a valuable contribution to knowledge. New ideas can be added to scientific research in this area of examination. A contribution to knowledge, based on a merged view on these three disciplines of decision-making, digitalization and supply chain management in specific is given by the author.

An analysis of the current status of research is given in the following chapter of this dissertation. Within this topic, the interaction between theory and practice is very important, to get a feedback loop in both directions. Moreover, in the progress of this dissertation the detailed view of theories will be validated by secondary research and an empirical approach in the following chapters.

2. RESEARCH REVIEW OF DIGITALIZATION OF DECISION-MAKING IN SUPPLY CHAIN MANAGEMENT

Chapter 2 will give an overview of already applied researches in the field of digitalization of decision-making in supply chain management. Actuality and relevance of the topic is given, because the effect of digitalization in decision-making forces organizations to act. Analyzing general trends of performance increases in organizations are often related to digitalization. The trend is a new composition of global organizations, which are relevant for the global economic system. Exhibit the readiness of countries for digitalization as an important precondition for digitalization, the infrastructure for digitalization has to be managed on economy level. The historic view on the development of digitalization of decision-making will classify the topic in traditional theories (Kondratieff waves) and the structure of organizations (most valuable companies). Analyzing "Gartner Hype Cycle" will increase the understanding of new applications in the field of digitalization of decision-making and explain "what will change". The following question of "how to change" is exhibited with a Fraunhofer model and the model of "Digital Masters". Further researches in digitalization areas smart data, automation, integration, digital customer access and new business models will exhibit the current status of researches always related to supply chain management.

2.1. Actuality and Relevance of Digitalization of Decision-Making Performance in Supply Chain Management

Capturing the intensity of digitalization, a central precondition was necessary – globalization. Globalization is the international integration arising from the interchange of world views, products, ideas and other aspects of culture.[172] "Globalization is further defined as a process of interaction and integration among people, companies, and governments of different nations cross borders. This process is driven by international trade and investment. Enabling trade and investment on a global level, information technology is a valuable and effective tool. The globalization process has effects on environment, on culture, on political systems, on economic development and prosperity, furthermore on human physical well-being in societies around the world."[173] The global phenomenon of business technology diffusion is worth to discuss in detail, because globalization and digitalization have mutual causes. Globalization is a precondition for an effective digitalization of globally acting organizations. Globalization is not a new phenomenon of the last years or decades. Free-trade started centuries ago, but with the discovery of the American continent free-trade developed on a larger scale. The steps of globalization are explained in table 2-1 „Phases of Globalization" based on Klaus M. Kohlöffel and Klaus-Jürgen August. The author added a forth phase of globalization, because today digitalization is the driver for globalization.

[172] Albrow M. & King E.,1990. Globalization, Knowledge and Society. London: SAGE
[173] http://www.globalization101.org Accessed: 22.01.2018

Phases of Globalization *Table 2-1*

Era of Globalization	Period	Driver of Globalization	Main Question
Globalization 1.0 The world is shrinking in our cognition from big to medium-size	Starting 1492, up to free-trade of old and new world around 1800	Countries and muscles	Which role plays my country in global competition?
Globalization 2.0 The world is shrinking in our cognition from medium-size to small	From 1800 to 2000	Multinational enterprises and industrial revolution	Which role plays my enterprise in global competition?
Globalization 3.0 The world is shrinking in our cognition from small to extra-small	From 2000 to now	Energy of individuals to cooperate and compete on a global scale	Which role I play in global competition?
Globalization 4.0 The world is shrinking in our cognition to tiny – the world is a global village	From today on	Digitalization	Which role play machines in global competition?

(Author's construction, based on Klaus M. Kohlöffel and Hans-Jürgen August[174])

Focusing on the economies of scale effects, digitalization is an exciting example for this effect on a global scale.[175] Economies of scale, as described by Paul Krugman, is not a new idea of globalization, but with digitalization tools, this effect intensifies the globalization process. The main aspect of transaction costs - costs which will be created by making a transaction - will be reduced dramatically by using digital tools, e.g. supply chain costs or costs for insurance. This effect of transaction cost reduction is given for both parties, hence both participants of a transaction benefit from cost advantages and more transactions will be pushed. Therefore, globalization and digitalization are moving hand in hand respectively one calls the other. Important for the compelling success of digitalization in a globalized world is a significant cost advantage. Digital tools and setups will generate, by implementing and rolling out on a large scale, massive cost savings for organizations. Digital features enable an increased competitive position in the market, because global markets have a broader base of collaboration for products (tangible or intangible), services or investments. Hence, the economy of scale theory is applicable for this trend.

An organization is not a closed system, it is affected or triggered from outside events. Consequently, organizations are open systems and are part of a "super-system" – the (virtual) market environment.[176] Endogenous events will create reactions and activities in organizations, to respond to market

[174] Kohlöffel K.M. & August H.-J., 2012. Veränderungskonzepte und Strategische Transformation. Publicis Publishing. Erlangen. P. 14
[175] Krugman P., 12-1980. Scale Economies, Product Differentiation, and the Pattern of Trade. The American Economic Review. Vol. 70, No. 5 (Dec., 1980). Pp. 950-959
[176] Ropohl G. 2012. Allgemeine Systemtheorie. Berlin. Deutsche Nationalbibliothek

movements. Especially in the current environment, these effects rise tremendously, because entire market environments and its behavior are changing dramatically. Changed customer structures and behavior in combination with new competitors are manifold and given in all industries. Production and supply chain have a huge variety of possibilities and a high speed of time to market is linked with shorter product life cycles. Even political streams of protectionism, like BREXIT or tariff barriers (USA), are currently increasing the uncertainty in business. These elements have to be managed in the subsystem organization just as well. From an inside view of an organization, the market environment will also be influenced, as a feedback loop to market changes. Depending on the critical mass of organizational changes, a change in the entire market system may occur. Understanding these dynamic market movements in today's world, the need for a clever digital setup of a decision-making system in an organization is essential. New digital elements create efficiency and quality in decision-making.

The precursory effect of digitalization, strong growth of global corporates is worth to analyze. The German newspaper Handelsblatt published the following figures of the "Forbes Global 2.000" corporates. These are the biggest corporates in the world, in terms of revenue, profit, market capitalization and employees.[177]

Forbes Global 2.000 Corporates Over Time *Table 2-2*

Forbes Global 2.000 Corporates	**2003**	**2013**	**2018**
Revenue (in trillion USD)	19	38	39
Profit (in trillion USD)	0,8	3,0	3,2
Market Capitalization (in trillion USD)	24	44	56
Employee (in million people)	64	90	--

(Author's construction, based on Forbes Global)

As shown in table 2-2 „Forbes Global 2.000 Corporates Over Time" corporates doubled their revenue and hence the underlying operating performance from 19 to 38 trillion USD (+100%). The profit level almost tripled (+275%). In comparison to the performance key figure "Return on Sales"-quota (relation from profit to revenue), the "Forbes Global 2.000" corporates almost doubled this performance figure from 4.2% up to 7.9%. The strong profit increase, with strong revenue growth, is very impressing, because quite often revenue expansion and profit erosion are running hand in hand. Hence the profit improvement effect seems to be related to a huge efficiency progress in these corporates. This is expressed in the figure „Employees (in million people)". The increase from 2003 to 2013 was from 64 to 90 million people, a growth of only +41%, compared to a doubling of revenue and operating performance. Growing your business even stronger than adding people on the same level, means that – beside the economies of scale effect - automatization took place in these corporates. This automation is related to the topic digitalization and globalization. Especially Hewlett-Packard was aware of this topic

[177] Handelsblatt Germany, 06.08.2014

and changed dramatically the own Supply Chain management environment to improve margins: "HP identified the need to improve its process for manufacturing and delivering products to customers as profit margins suffered pressure from increasing competition."[178]

A further aspect of digitalization and globalization is discussed by Michael L. Katz and Carl Shapiro with their view on „Systems Competition and Network Effects". Products with little or almost no value, may generate value by the combination with others, especially by the combination of software and hardware. These ideas were summarized in a research from above mentioned authors. When a system is chosen and after that, switching suppliers may become costly, because of specific spending for a new system. Hence, the investment into systems that may expected to become popular will be chosen. Based on this assumption, this system is becoming more popular and will succeed in the market. Then the membership of one user of this system is positively affected when another user joins the system and therefore enlarge the network for this system - the value of this network is increasing. In research it is known as „network effects" or „network externalities". Recently this effect is proven in a software and hardware relationship, and known as „software/hardware paradigm". For an endurable decision three factors are relevant:

1. Technology adaption decisions: e.g. how many consumers purchase a system?
2. Product selection decisions: e.g. what forces consumers' choice among rival systems?
3. Compatibility decisions: How do intellectual property or social incentives influence compatible system choice?

These effects have some challenges to range into economic theory. Because network effects are not fitting into the logic system of economy, to operate with scarce resources and the related allocation of it. As a given result, understanding and using "network externalities" will increase value for organizations and their systems. [179]

A similar analysis was undertaken by Robert Metcalfe. The utility of a communication system is growing in square by the number of users. In 1980s, Robert Metcalfe, the inventor of Ethernet, proposed a formulation of network value in terms of the network size (the number of nodes of a network), which was later named as Metcalfe's law. The law states that the value V of a network is proportional to the square of the size n of the network. Metcalfe's law has been influential and an embodiment of the network effect concept, but also generated many controversies. Some scholars went so far as to state "Metcalfe's law is wrong" and "dangerous". Odlyzko and Tilly state in general, if connections are not used in the same intensity, assigning an equal value to them, it is not constructive. Especially in large networks, the usage of it (e.g. Internet) is not similar.[180] Despite these arguments, for 30 years, no evidence based on real data was available for or against Metcalfe's law. The situation changed in late

[178] Davis T., 1993. Effective Supply Chain Management. Sloan Management Review. Summer 1993. P. 35
[179] Katz M. L. and Shapiro C., 1994. Systems Competition and Network Effects. Journal of Economic Perspectives. Volume 8, No. 2. Spring 1994. Pp. 93-115
[180] Odlyzko A. & Tilly B., 2005. A refutation of Metcalfe's Law and a better estimate for the value of networks and network connections. March 2, 2005. Digital Technology Center, University of Minnesota, USA. Accessed: 02.04.2020

2013, when Metcalfe himself used Facebook's data over the past 10 years to show a good fit for Metcalfe's law.[181]

A dedicated effect of getting cost advantages on digitalization in line with globalization, is the cost structure effect of discussed applications. Software components and hardware devices are more and more decoupled, as a new trend. Creating value of this well thought out combination from independent software and hardware components, will change the structure and the opportunities for decision-making. The user selects independently both parts for the individual digital setup and is able to create, on a large scale, these possibilities. As example, smart phone devices are mainly standardized today, compared to years ago, when there had been lot of variants of cellular phones with a huge differentiation in hardware. Today the differentiation is done by software components, namely "Apps" to create an individual value for each user. Hence every smart phone combination of hardware and downloaded software is after some weeks of usage a unique product with a significant value for each individual user in terms of a perfect fit for the particular individuum. This trend of decoupling software and hardware created massive advantages in hardware production with the reduction of variants and gains in marginal costs. The production structure of software is characterized by a huge effort of compiling the software the first time, but then duplicating the software is simple, for marginal costs. The cost structure of software is mainly driven by fixed costs for the first unit and a small proportion of variable costs. This cost structure is quite interesting for a further distribution of software licenses, because marginal costs are close to zero. This effect of zero marginal costs for software licenses is a main driver for a global distribution of software, because there is almost no further expenditure for organizations. The only additional costs are based on language packages for customization. Focusing on fragmented markets, the costs per unit would be tremendously high, but on a global scale, the costs per unit for software licenses will be allocated on a broader global population. This phenomenon of the digital era is the effect for a required global distribution of software components or related features and supported the increase of data driven organizations on a global level.[182]

As discussed above, the diverge of software and hardware is a technological quantum leap for more developed applications in the digital era. Because of a more independent design of software, creation of new possibilities made progress in the recent years. Installation of software in a completely distributed hardware environment is nowadays possible. While this change, software really changed in two different layers of software, application and implementation (functional and non-functional aspects). Application layer and implementation layer is the split between requirements of users (making photos, book a hotel or listen to music) and technical internals of a system (conversion of data or send a message via internet). The distinction between functional and non-functional aspects, is for functional aspects, e.g. transmission of data or playing music. Non-functional aspects are for instance, operating interface, fast running software or security and integrity. Integrity means, a system behavior in an expected way including data security and propriety. Contemporary view on integrity is, because of open system environments, more important than ever. Therefore, data integrity (data in the system are correct and

[181] X.Z. Zhang & J. J. Liu & Z.W. Xu. 03-2015. Tencent and Facebook Data Validate Metcalfe's Law. Journal of Computer Science and Technology. March 2015, Volume 30, Issue 2. Pp. 246–251

[182] Picot A. & Reichwald R. & Wigand R. 2001. Die grenzenlose Unternehmung. München. Gabler Verlag. P. 63

consistent), behavioral integrity (the system behaves as expected) and security (the system limits access on authorized users), is a very important structure for current software systems. The architecture of software changed in the last years; well-known and implemented centralized system architecture in contrast to distributed system architecture. For a better understanding of the structural design of distributed and central systems, figure 2-1 „Distributed Systems vs. Central Systems“ will increase the understanding of the topic. These systems have a higher processing power on lower costs and are more reliable combined with the possibility for natural growth (adding further computers to the total system).[183] This concept will support the digitalization of supply chain management with the structure of a described layout, e.g. blockchain technology. A key development in the recent years was blockchain technology. This technology is a distributed solution and enables new digital capabilities for organizations. In brief, blockchain is a tool, to reach integrity in distributed software systems. Therefore, blockchain is a tool to fulfill all non-functional aspects of the implementation layer.[184] Blockchain technology is a relevant application for decision-making in supply chain management, by gaining process efficiency.

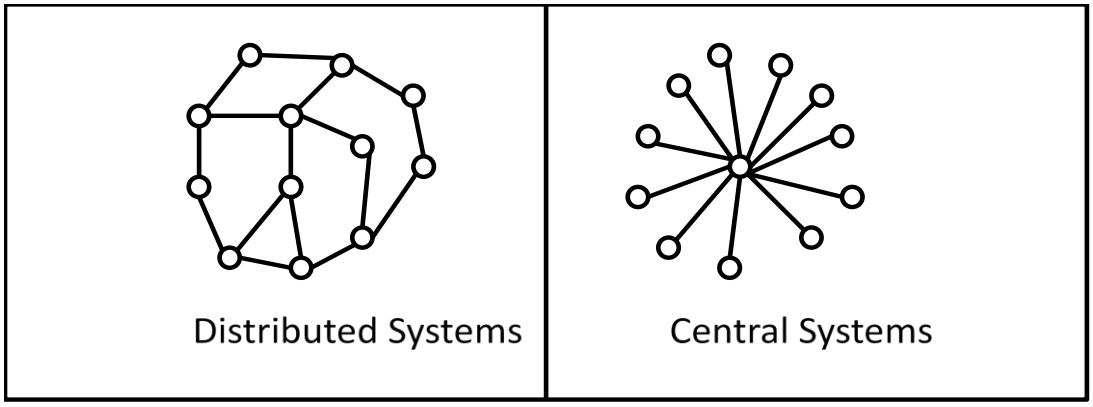

Figure 2-1 **Distributed Systems vs. Central Systems**

(Author’s construction, based on Drescher)

„Because managers are subject to various psychological and organizational biases when evaluating previous strategic decisions, especially when the outcomes of those decisions are undesirable, it is difficult to maintain strategic flexibility. The uncertainty exacerbates the challenges in making decisions about whether to continue commitment to previous strategic decisions or to change them.“[185] This uncertainty on the strategic level of decision-making is a challenge for an organization and managers, therefore any support to obtain a higher level of certainty seems to be beneficial for a qualitative decision

[183] Drescher D., 2017. Blockchain Grundlagen – Eine Einführung in die elementaren Konzepte in 25 Schritten. Mitp Verlag. Frechen. Pp. 24
[184] Drescher D., 2017. Blockchain Grundlagen – Eine Einführung in die elementaren Konzepte in 25 Schritten. Mitp Verlag. Frechen. Pp. 36
[185] Katsuhiko Shimizu and Michael A., 11-2004. Strategic Flexibility: Organizational Preparedness to Reverse Ineffective Strategic Decisions. Source: The Academy of Management Executive (1993-2005), Vol. 18, No. 4, Decision-Making and Firm Success (Nov., 2004), pp. 44-59 Published by: Academy of Management Stable URL: http://www.jstor.org/stable/4166123 Accessed: 30.10.2017

by minimizing risk and mistakes. A digital system which supports decision-making or decide autonomous, will increase the certainty for a decision, based on a reliable algorithmic model.

Analyzing the trend of digitalization will exhibit, that not a single organization will change the technological structure itself, because this change has to be managed on a broader scale. The volumes of investments would be to expansive for only one organization. Economies and governments have to create the prerequisites for standards and infrastructure, ideally on a global approach and international cooperation. Therefore, the country ranking of "World Economic Forum" points out the relevance for the readiness of digitalization of countries. The global IT report of World Economic Forum (WEF) shows the following results:[186]

The question had been „In your country, to what extent do businesses adopt new technology?" (1 = not at all; 7 = adopt extensively). The first 15 countries out of 143 were:

Ranking Firm-Level New Technology Adoption *Table 2-3*

Rank (top 15)	**Country**	**Economy Value**
1	Iceland	6,2
2	Japan	6,1
3	United States	6,1
4	Norway	6,1
5	Israel	6,0
6	Switzerland	6,0
7	UAE	6,0
8	Luxembourg	6,0
9	Sweden	6,0
10	Finland	5,8
11	New Zealand	5,8
12	Qatar	5,8
13	Germany	5,7
14	United Kingdom	5,7
15	Denmark	5,7
Mean (of 143 countries)		**4,7**

(Autor's construction)

Table 2-3 shows an important trend, because the adoption of new technology assumes that digitalization in these countries is given. This should improve the opportunity for a digital transformation in the particular country, broke down to the next systematic structure, on organizational level. As a perfect solution, digitalization will not stop at country borders, a collaboration between countries would be desirable, because increased digitalization opportunities will trigger a higher GDP for all involved countries.

[186] World Economic Forum. 2015. The Global Information Technology Report 2015. Accessed: 31.05.2016

2.2. Research Review of Digitalization of Decision-Making in Supply Chain Management

Researches on decision-making are manifold, based on the scientific discipline, the research purpose and the related research question. A limitation of the review for this dissertation is consequently purposeful edited, to achieve a better understanding for the research question and related hypothesis. Researches in decision-making are a traditional assignment, with a huge quantity of underlying contributions to the theoretical and practical content of this scientific discipline. Researches in the interface between decision-making and digitalization are essential, because both scientific fields are dependent on each other. For decision-making, from a mathematical and statistical point of view, automated calculation is a basic prerequisite to evaluate required models. For digitalization, researches had been also done, while the development of the discipline in computer sciences and similar to the field of supply chain management. Finally, the combination of all topics in a scientific approach exhibit currently limited sources of research, due to the latest manifold developments in this area. Today, the view on researches of the topic digitalization of decision-making has a particular significance, because decision-making, driven by a digital setup is highly distributed between scientific research and private initiated researches. Therefore, a view on practical (business driven) researches is supportive, to receive a complete picture of the current status from the dissertation's topic, in science and practice. The author decided for a mixed view on researches, which will be discussed in this dissertation.

2.2.1. Historical View on Research

From a theoretical point of view, many trends in business created new behavior and environments for economies. These effects had been analyzed by Nikolai Kondratieff in his theory of long economic waves. Based on his theory, changes in economic paradigms in long waves and the reason of long-term dynamics of our socioeconomic and technological system are evident. These changes of technology create economic growth and started with industrialization of economies. As analyzed by Kondratieff, these long-term waves (52 to 53 years) finished already their fifth cycle, namely the first wave was the start of industrialization with steam engines and the birth of a new type of economies. Then the second wave was the time of railroads which increased the possibility to exchange goods over a longer distance between related parties. The third wave was driven by electrical engineering and heavy industries, which changed the economies and their mechanisms again. Further, the fourth wave was automation with electric circuits including the first models of computers and automobiles. Finally, the fifth wave was based on information and communication technology and the starting point for economies as we know today, with increased automation, integration and communication.[187] Putting these cycles into context to digitalization, starting in 2008 and 2009 with the latest financial crisis, interesting observations had

[187] Korotayev A. & Tsirel S., 07-2010. A Spectral Analysis of World GDP Dynamics: Kondratieff Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis. Structure and Dynamics Journal, 4(1). https://cloudfront.escholarship.org/dist/prd/content/qt9jv108xp/qt9jv108xp.pdf Accessed: 01.04.2018

been made by Markku Wilenius. He analyzed a quite important part of the current economic situation and the transition from wave five to wave six of Kondratieff's theory. His view is, that the financial crisis has marked the inevitable shift from the fifth to the sixth wave of development. This idea states, that the principles on which the economic system stands, become outdated as the wave moves towards the end. On the systemic level we can easily verify that, liberalization of the financial markets led to the kind of behaviors and instruments that ultimately hassle the performance of the Western economies. When this coincided with the behavior of many European governments, the result was a massive stagnation of economies. All this had happened before, because in each major financial crisis in industrial economies, the Panic of 1837, the Long Depression of 1878, the Great Depression in 1929 and the Oil Crises of 1973 and 1980, there had been a trend toward new technologies, for the idea of Kondratieff's long-waves theory. First of all, creating productivity increase, keeping interest rates high, then the driver begins to be exhausted with less return for investments, interest rates getting down to zero as the demand for credit slows and inevitably the crash is created. Kondratieff himself postulated four major signs for a new cycle. First, appearing of massive basic innovation. Second, an excessive amount of financial capital has accumulated. Third, it appears a passage of severe recession, a gateway for radical change. And fourth, surplus of institutional and social changes occurs, leading to new organizational cultures. As we may observe from the current situation, all these criteria were met in the context of the financial crisis. The aftermath that followed, with new economic and political aspirations, the beginning of the new socio-economic cycle is marked. Inevitably, this had been the starting point for the digital age, the sixth Kondratieff's wave, with all the corner stones described above.[188] Some years after the financial crisis an evaluation of Kondratieff's theory seems elementary. From this point of view, the following interesting question is, how economical, technological, social and cultural changes can be analyzed and predicted, using Kondratieff's theory of long waves. Generally, the theory states that each cycle shows the following events:

- New industries emerge, replacing the old ones
- A new extended economic boom sets in, with the rise of equity markets
- New value systems begin to dominate, governing public debate and planning
- New professions and skill standards appear
- New corporate cultures begin to dominate

The new cycle may bring new economic incentives and new social environments. Whereas in the previous cycle, the spread of new technology led to a dramatic increase in the productivity of labor. Assumptions are predicted from environmental, micro- and bio-based technologies, leading to an increase in productivity in the use of raw materials and energy.[189] Understanding this change, an analysis of big corporates seems supportive for further examinations. The best view on new industries and companies is given at the stock exchange, because financial investments are a driver for change, as displayed before in the remarks of the long waves in Kondratieff's theory. Therefore, a view on the New

[188] Wilenius M., 03-2014. Leadership in the sixth wave - excursions into the new paradigm of the Kondratieff cycle 2010–2050. European Journal of Futures Research. P. 2. Springerlink.com. Accessed: 01.04.2018
[189] Wilenius M., 03-2014. Leadership in the sixth wave - excursions into the new paradigm of the Kondratieff cycle 2010–2050. European Journal of Futures Research. P. 3. Springerlink.com. Accessed: 01.04.2018

York Stock Exchange should connect to the sixth long wave on Kondratieff's theory and adumbrate a tremendous change in Western economies.

Data Driven Companies Have Become the Most Valuable *Table 2-4*

Market Capitalization of Companies Worldwide				
Rank	**April 2017**		**December 2006**	
	Company	**(in bn USD)**	**Company**	**(in bn USD)**
1	Apple	741	Exxon Mobil	447
2	Alphabet	585	General Electric	384
3	Microsoft	505	Microsoft	294
4	Amazon	432	Citigroup	274
5	Facebook	408	Gazprom	271
6	Berkshire Hathaway	404	ICBC	255
7	Exxon Mobil	344	Toyota	241
8	Johnson & Johnson	330	Bank of America	240
9	JP Morgan Chase	303	Royal Dutch Shell	226
10	Alibaba Group	278	BP	219

(Author's construction, based on S&P Capital IQ[190])

Analyzing the most valuable companies of the world, the development toward data driven organizations is displayed in table 2-4. In 2017, 6 out of 10 companies had been in a new data driven industry. Traditional organizations and industries are losing value, e.g. Exxon Mobil, in 2006 value of 447 bn USD reduced to a value of 344 bn USD in 2017. This is a clear sign of a structural change, based on Kondratieff's sixth long wave. Important to understand in context of globalization, country borders or local jurisdictions lost relevance for these new companies, because these organizations act on a global level nearly borderless with their product portfolio.

Change in consumer behavior and more fragmented markets require a perfect tailored supply chain solution to manage these costs on an efficient level. As an example, Kreutzer and Land exhibit the trend to fragmentation of markets. In the past, Procter & Gamble reached with 3 TV spots 80% of the American women aged between 18 and 49. In 2012 97 TV spots were necessary to achieve the same goal. This fragmentation is on product and packaging level similar. Different features on products are installed for different consumer groups and packaging is based on either consumer groups or events.[191] Therefore the new companies, with their flexible product offerings, are quite successful.

This general view on historical data puts context to the topic of digitalization and decision-making in organizations. Early ideas of Bayes, Bernoulli or Fermat had been part in both theories, in computer sciences and decision-making, hence a relationship of both theories is demonstrated. As described in the

[190] S&P Capital IQ. Top 10 Companies with Highest Market Capitalization Worldwide. https://www.bcg.com/publications/2017/digital-transformation-transformation-data-driven-transformation.aspx. Accessed: 02.10.2017

[191] Kreutzer R. & Land KH. 2015. Digital Darwinism – Branding and Business Models in Jeopardy. Berlin. Springer Verlag. P. 46

historical part of digitalization and decision-making, quite the same name of scientists of decision-making and digitalization appeared, e.g. von Neumann, which was an important scientist in decision-making and computer science.

2.2.2. Research Review of Digitalization of Decision-Making

The concept to analyze strategic decision-making in organizations based on the digital setup, is an area of difficulties. First, the definition of a digitalization of a decision is important, having a clear scope for the analysis. The definition of digitalization for this dissertation is done in the theoretical chapter and exhibits the focus on the mentioned digitalization areas (smart data, automation, integration, digital customer access, new business models), which are relevant for decision-making. To get a better understanding, applications of digitalization should be in scope of the research and then be classified within the digitalization areas. The idea to approach this topic from general to detailed level is the direction of analysis.

First of all, the "what will change" should be in scope of organizations, with all relevant influencing factors. Technology is the key driver for new applications. Bringing context into the research of digitalization of decision-making, the view on „Gartner Hype Cycle" is a constructive possibility to narrow the wide range of current activities in the field of digital applications in relation to decision-making. This overview of Gartner group exhibits a good combination of latest technology and economical utilization. „Gartner Hype Cycle" provides a graphical representation of the maturity and adoption of technologies, based on applications, and how these are potentially relevant to solve real business problems or exploit new business opportunities. The applied methodology gives a view of how a technology or application will evolve over time, providing a source of analysis, to manage its deployment within the context of specific business goals. The general graph looks as in figure 2-2 „Gartner Hype Cycle" displayed, with an ideal modeled trend.

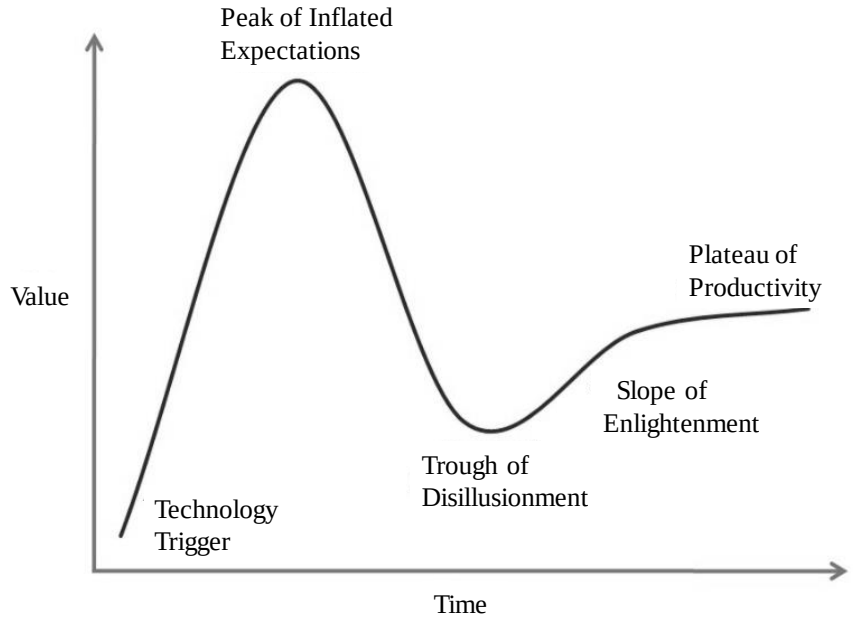

Figure 2-2 **Gartner Hype Cycle**

(Author's construction, based on Gartner group)

The idea of the „Gartner Hype Cycle" [192] is, to exhibit the relevance of new technology, transformed into economic success. The legend on the x-axis is the time and on the y-axis the value of an innovation. The typical flow, from an idea to exorbitant expectations is raising in a strong line up (in the phase of a technology trigger), to the climax called „peak of inflated expectations", and then calming down to more realistic expectations, called „trough of disillusionment". After this development the trend is getting a further move of improvement named „slope of enlightenment". Finally, on a higher „plateau of productivity" the level of a successful product or service is realized.

The general pattern has shown in the year 2017 the following trend as displayed in figure 2-3 „Gartner Hype Cycle Model in 2017". Early ideas, like smart dust (a system of many tiny micro-electro-mechanical systems such as sensors, robots, or other devices, that can detect, i.e. light, temperature, vibration, magnetism, or chemicals), 4D printing (3D printing additional the fourth dimension "time" as printing objects which reshape themselves or self-assemble over time) or connected home. More discussed in publicity, business and science are the trends of deep learning, machine learning or cognitive computing/advising which were in 2017 on the maximum level of expectations and now will „recalm". Virtual and augmented reality is today on the "plateau of productivity", with well-known products like smart glasses, with the possibility to be full or mixed in virtual reality.

These trends are very important for a better understanding of the latest developments in digitalization of decision-making. The way forward to autonomous decisions or decision support is mainly given by the areas of digitalization, mentioned in the last chapter. From this follows, that a focus should be on the areas of automation, integration, smart data, digital customer access and new business models. Figure

[192] Gartner Group. 2018. Gartner Hype Cycle. https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp. Accessed: 01.04.2018

2-3 „Gartner Hype Cycle Model 2017“ [193] shows a very direct view on digitalization of decision-making models and the trend of a movement from human respectively analogue decisions to digital decision models, like deep and machine learning, smart robots, cognitive computing and expert advisors. These are the applications for digitalization of decision-making, developed on a marketable level. The next development of digital decision models is arising by brain-computer interface, digital twins, human augmentation and deep reinforcement learning, finally artificial general intelligence and smart dust.

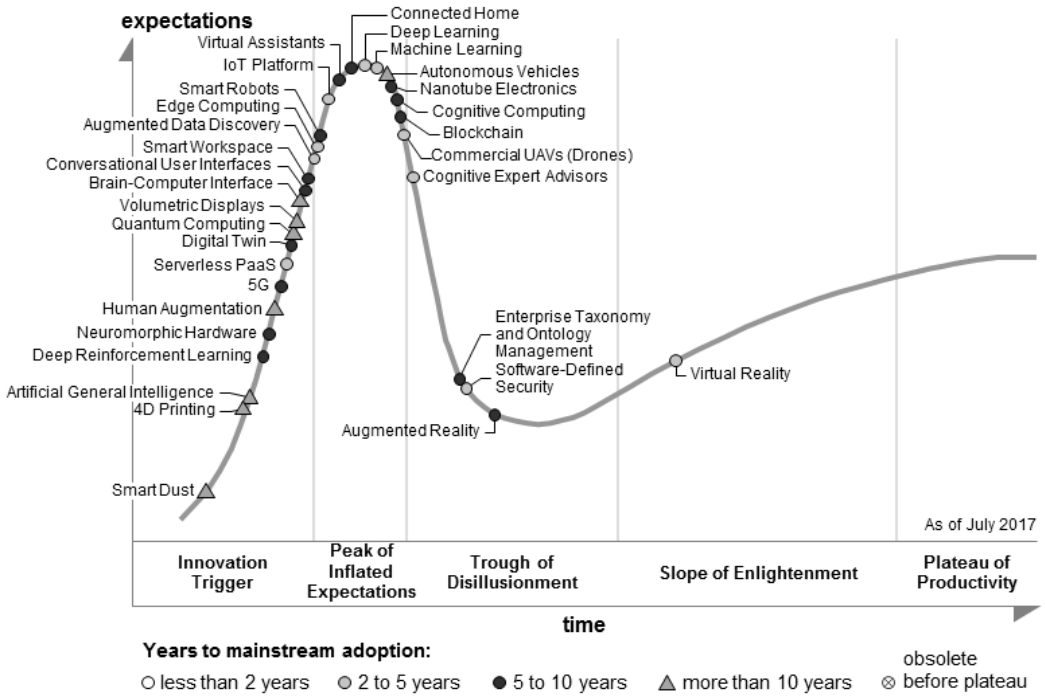

Figure 2-3 **Gartner Hype Cycle Model in 2017**

(Author’s construction, based on Gartner group)

Further research is done by manifold parties in this field. Latest developments were mainly done by private-owned organizations with a dedicated scope. KPMG, BCG and McKinsey are well named consulting organizations with huge research departments in this field. In Germany, the Fraunhofer-Institute, a public-private-owned organization is a key player and also well-known for their researches in digitalization. Further public organizations, as German government, world bank or IMF (International Monetary Funds), also published researches on this contemporary topic.

Moving top-down and narrow the view on decision-making, today it’s not purely related to autonomous decisions. The view of current research is often related to decision support systems. These systems are the precursor of digital autonomous decisions. Decision support systems developed over the last decades in the wide area of automation and integration, in research and in practice. But these systems do not focus on autonomous decisions, in this environment it is more defined in a first step as a decision preparation and the final decision is a based on human judgement or interaction.

[193] Gartner Group. https://www.gartner.com/newsroom/id/3784363. Accessed: 01.04.2018

Years ago, the first ideas of digitalization of decision-making was introduced by the CIM concept. This „Computer Integrated Manufacturing“ concept had the first ideas for automized decisions in a manufacturing environment. Due to technical and processing limitations, these concepts failed in the past and did not accomplish in business. But now with increased processing power and new technological setup of systems, the idea of CIM is coming back to organizations, with an updated version of latest technology. The traditional concept of having interfaces between systems and then transfer data through these interfaces, is now replaced by a service driven infrastructure with an increased flexibility of data flows, as described before with distributed systems. In the perfect world, there is only one interface remaining into the cloud with maximum flexibility. Production shadow technology is now possible, real production is simulated in real-time, in a digital environment and will enable predicative solutions with a minimum of reaction speed.[194]

In a next step, the “how to change” should be on the agenda of organizations. For a certain extent, an intelligent digital setup is individual for every organization, but the main conceptual model of digitalization for organizations is designed as a generic digitalization model for general purposes. One example for a sophisticated generic model of digitalization is designed by Fraunhofer Institute in Germany and a supportive framework for organizations executing these ideas. This is a split into an internal view and an external view, with a scope on smart products and digital services as a key element, as displayed in figure 2-4 „Digital Map of Organizations“. The connecting brackets of internal and external view are finally a digital business model, which is essential for the intelligent digital setup of an organization. These two dimensions of „how to manage the digitalization“ and „what to manage in terms of products and services“ is the structure and a roadmap for a digital transformation.

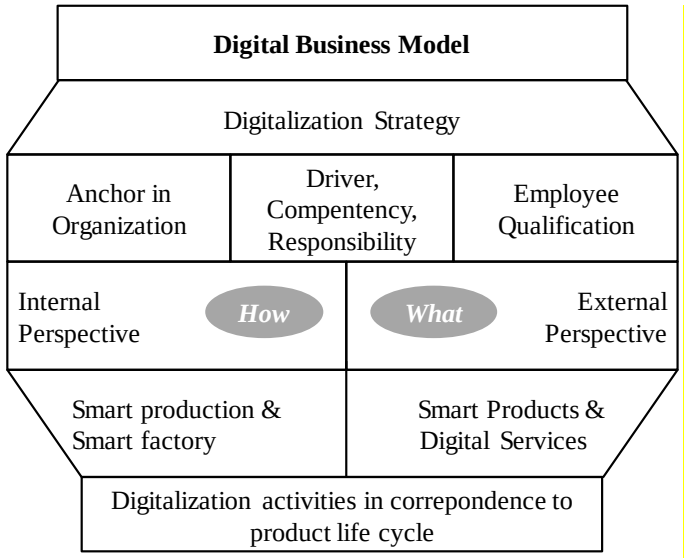

Figure 2-4 **Digital Map of Organizations**

(Author’s construction based on Fraunhofer model[195])

[194] McFarlane D.C., 1995. Holonic Manufacturing Systems in Continuous Processing: Concepts and Control Requirements. In Proceedings of ASI’ 95, Portugal, June, 1995. Industrial Control Centre, University of Westminster
[195] Fraunhofer IPA. 2017. Digitalisierung im Mittelstand – Entscheidungsgrundlagen und Handlungsempfehlungen. Stuttgart. Pp. 26

The definition of the term „organization“ is essential, because of a broad usage of the term organization. A definition of an organization is a wide area in science with ambiguous definitions. A historical view is useful for the definition of organizations. Classical organization theory starts with Taylor and his view on physical activities in production, based on time and method studies. To limit the focus, there are three major approaches of organizational theory. The first ideas of organizational structures and division of labor is reaching back to the early years of the last century and is defined by well-known scientists like Frederick Winslow Taylor (scientific approach – increase production efficiency and productivity by separation of duties - division of work between managers and workers[196]), Henri Fayol (administrative management theory – general principles of administration and management – plan, organize, command, coordinate and control[197]) and Maximilian Carl Emil Weber (bureaucracy model – rules and documentation – hierarchies, written rules, power of management, documented decisions[198]). The second one is a social psychological approach with an experimental base on efficiency. The third approach is administrative and it focuses on the issues of how executives are dealing with organizations. In this environment Cyert and March – based on organizational theory – approached this for decision-making.[199] Furthermore, focusing on structure, organizations are mostly seen as hierarchies. Hierarchical descriptions are often used, because sometimes it's seen that organizations deliver more efficiency, sometimes hierarchical orderings fit more in general culture norms for describing social relations in terms of domination and subordination.[200] Understanding organizations in the context of decision-making, the view that participants of these organizations or the organizational unit itself is an important element for decision-making (based on the activities), the organization is responsible for. From this view, digitalization of decision-making is a reasonable development in organizations, because the core task, to execute these activities, is not depending on a human or digital decision.

When the generic model of "how to change" is set, a more detailed plan should be designed. Westerman, Bonnet and McAffee are describing organizations, which transformed their business model toward a digital organization as shown in figure 2-5 "Digital Masters". Revenue and profit of these organizations increased, compared to the industry benchmark tremendously. These "digital masters" realize a plus of 26% more profit and a plus of 9% higher revenue from their physical assets, compared to their industry peers. Understanding the analysis of Westerman, Bonnet and McAffee in full width, the structure of the model is very important. Key for an organizational development is the main capabilities of an organization, digital and leadership capabilities. The model is designed on the x-axis with "leadership capability" and on the y-axis with "digital capability" and shows the development stage of organizations in term of their digital leadership status.[201]

[196] Taylor F.W., 09-2004. The Principles of Scientific Management. Original published 1911. EBook #6435. Gutenberg Project. http://public-library.uk/pdfs/8/917.pdf. Accessed: 07.04.2018
[197] Fayol H., 1916. Administration Industrielle et Generale. https://www.kullabs.com/classes/subjects/units/lessons/notes/note-detail/4439. Accessed: 18.04.2018
[198] Weber M., 1922. Wirtschaft und Gesellschaft. Teil 3 Typen der Herrschaft, Kapitel 6 Bureaukratie. https://www.kullabs.com/classes/subjects/units/lessons/notes/note-detail/5329. Accessed: 18.04.2018
[199] Cyert R.M. & March J.G.1992. A Behavioral Theory of a Firm. Cambridge and Oxford: Blackwell
[200]March J. & Simon H.A., 1997. Organizations. Cambridge and Oxford: Blackwell. P. 3
[201] Capgemini Consulting. 2018. Understanding Digital Mastery Today. https://www.capgemini.com/wp-content/uploads/2018/07/Digital-Mastery-DTI-report_20180704_web.pdf. Accessed: 10.10.2019

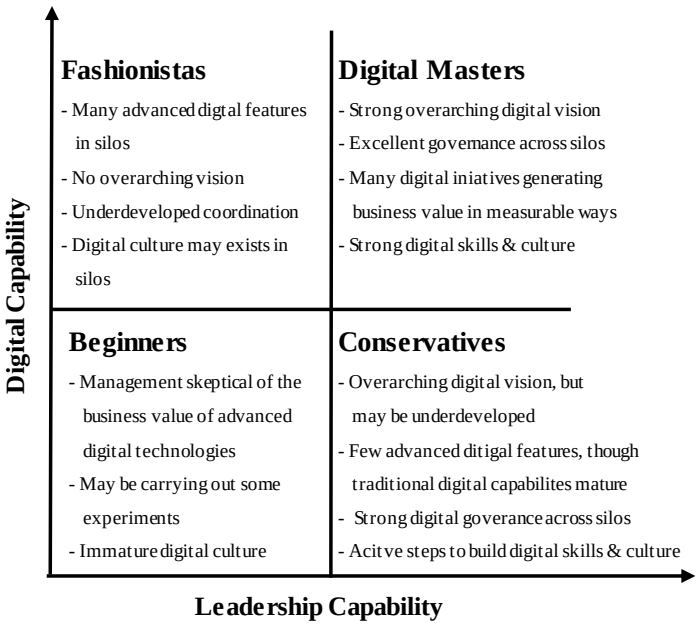

Figure 2-5 **Digital Masters**

(Author's construction based on Westerman, Bonnet & McAffee, Capgemini)

Referring to the "structured professionals interview" in the third chapter, a similar survey was done with 4.800 executives and managers across 27 industries. These managers and executives were asked regarding digital technologies, transforming their business, by MIT Sloan Management Review and Deloitte. As a significant result, the clarity of these managers that digitalization is disrupting their industries had been answered by 76% positively. Hence, the attention of these managers is focused on a digital strategy. Managers reported by 74% agreement, that their organization has a digital strategy. The ranking of digital evolution was done in three categories as „early", „developing" and „maturing" companies. 26% rated their organization as an „early" company, 45% rated their organization as a „developing" company and 29% rated their organization as a „maturing" company in the context of digital transformation.[202]

A Further survey was executed by EY in 2016 regarding the topic Industry 4.0. A random sample of 554 industrial companies and 152 ITC companies were asked. 79% of these organizations agreed to the strategic importance of Industry 4.0. These organizations mainly expect an increase of production flexibility (62%) and improved response time (57%). Cost reductions (30%) and improved customer support (28%) were rated on a lower level.[203]

Sadrieh discussed, on the platform of bounded rationality, with a view on human decision-making, „most of the research concerned with the question „Can an expert beat the market?" has concluded with the answer is: „In general, no.""[204] Even in this case, to predict the market, human cognitive performance

[202] „Digital Transformation of Business". 09-2015. Trends E-Magazine. P. 1-6
[203] Bley S. & Kilger C, & Vogel J., 2016. Industrie 4.0 – das unbekannte Wesen. Ernst & Young. Pp. 1 - 22. Accessed: 03.12.2017
[204] Sadrieh A., 2001. Is There Evidence for an Adaptive Toolbox? In: Bounded Rationality – The Adaptive Toolbox. USA. MIT, P. 72

is limited, but machines with cognitive intelligence are able to process in that way, as shown in the Gartner Hype Cycle before - as "cognitive expert advisors". This shows the development, that bots and AI are today important players for financial and capital markets. AI (artificial intelligence), e.g. robo-advisers are today in the role of making decisions autonomous on a qualified level, outgrowed of simple calculation exercises and prepared to beat human decisions. From 2008 on, this approach of robo-advisers gained steadily market share from their human counterparts. Key scope of financial assets management grew in the recent years and will grow in the next years tremendously. Deloitte is expecting 10% to 15% of the retail asset management market will be under AI control, in detail 5 to 7 trillion USD. Similar market expectations are communicated from Fitch Ratings and A.T. Kearney. Looking on corporate strategy, the ideas of financial asset management will be transferred into corporate departments and robo-advisers will process the massive data increase of financial and non-financial data. For automated and autonomous decision-making in these organizations the main goal is, to increase the quality and efficiency of these decisions. This is the view from consulting and advising industry, the qualified support is transferred into digital systems, ongoing with the reduction of human advisers on a broad scale.[205]

Hammerstein simulated a discussion between an economist and a biologist based on their view on decision-making and the cognitive limitation of humans. An outstanding reply of the biologist was as follows: „Under full rationality you have an organism that is supposed to be capable of correctly solving every mathematical problem – no matter how difficult – without any cognitive limitation, in zero time, and at no cost. That's some organism! Just imagine what kind of „super brain" it would have to possess, not to mention the fact that it wouldn't have to obey the laws of physics or the constraints of human physiology. Such an organism belongs in a science fiction novel."[206] This view on decision-making from a biologist is based on logical observations of humans with their limitations, which also is reflected in organizations. Taking new technologies and possibilities of machines with tremendous processing power into consideration, these decision models are not too far from reality, based on a digital setup. These super-computers exist today and use artificial intelligence based on deep learning to optimize decisions in designed algorithmic models, with self-learning structures. The learning curve is not based on programming by software engineers, this is done be the machine itself, collecting data and use this information for a broader view on making decisions, hence the decision itself will be improved over time. The era of digitalization on decision-making, supported by machines triggered traditional rational decision theories and had a comeback with all implications, based on algorithmic model designing. By creating a decision-making model, utility maximization is a core element, which will be strictly followed by a machine. Therefore, first time in history, it is possible to reach utility maximization in organizations, without any limitations, biases and heuristics. A further view on digital aspects in detail will deliver more content to the topic.

[205] Davenport D. & Libert B. & Beck M., 01-2018. Robo-Advisers Are Coming to Consulting and Corporate Strategy. Harvard Business Review. https://hbr.org/2018/01/robo-advisers-are-coming-to-consulting-and-corporate-strategy?referral=03759&cm_vc=rr_item_p..bottom Accessed: 26.01.2018

[206] Hammerstein P., 2001. Evolutionary Adaption and Economic Concept of Bounded Rationality. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT, P. 72

With a structured analysis of the **5 digitalization areas**, smart data, automation, integration, digital customer access and new business models, a significant development is given. These digitalization areas were directed by mentioned influencing factors. Examples of research will give a comprehensive overview of the current state.

The relevance of **smart data** is discussed in mentioned survey of EY with a value of 55% of frequency in Industry 4.0 context. Only machine-to-machine communication is more often mentioned with a value of 56%. This indication is relevant for the topic itself and for the structured professionals interview.[207] A further survey of KPMG and Bitkom Research GmbH in their 2015 report shows, that decisions are based on smart data, with an agreement of 75% to "relevant decisions in our organization are based on knowledge of data analytics". Further 61% agree to the relevance of data as a component for new business models or products. Finally, 63% believe, big data will show increased relevance in organizations. The random sample was based on 706 participants.[208] These studies are supported by M. Huberty's view on "the second big data revolution". His view on big data is, that data are the raw material for value creation in organizations.[209] Smart data, not necessarily big data are important to analyze in an appropriate speed of data converting and usage for data analysis. The everyday increasing amount of data will be analyzed completely automatically by machines, even the following data analytics will be done more likely by autonomous decision-making of machines and independent systems, without any further input or operations by human workforce. As quite often discussed, the quality of machine working is on a stable level and for every step repeatable, which ensures a high quality in the process. In case of errors, predominantly error detection is on an adequate level and mostly transparent for operators or maintenance personnel. As Marshall, Mueck and Shockley contributed, big data and analytics are key elements of successful organizations to innovate growth opportunities and generating an improved competitive advantage in their industry.[210] Request for transparency and corporate governance is always a strong need for organizations. Today's requirements for auditable processes are only possible with high efforts of documentation, procedures and rules for the organization. Humans should follow these rules with their decisions, but this need to be documented, because a human process execution need not to be exactly realized as expected. In the future in an autonomous decision process, the algorithmic model is the master design for the entire decision process. This approach is designed for corporate governance structures and will ensure a high level of transparency in the entire organization and minimize the efforts for audits. This new view of autonomous decision-making, with enormous possibilities of transparency will generate further efficiency in organizations. Many tasks will be eliminated in the field of audit and control. Further, K. Yeung focuses on how the data industry is harnessing smart data to transform personal data into economic value. Describing the technology of sifting, sorting and interrogating of vast quantities of data to process data mining for patterns, distilling into predictive analytics and applying the analytics for new data. The

[207] Bley S. & Kilger C, & Vogel J., 2016. Industrie 4.0 – das unbekannte Wesen. Ernst & Young. P. 8. Accessed: 03.12.2017
[208] Erwin T. & Heidkamp P, 2015. Mit Daten Werte schaffen – Report 2015. KPMG and Bitkom Research GmbH. Pp. 18. Accessed: 27.12.2017
[209] Huberty M., 2014. Awaiting the Second Big Data Revolution: From Digital Noise to Value Creation. Springer Online. Pp. 35 - 47. Accessed: 21.12.2017
[210] Marshall A. & Mueck S. & Shockley R., 2015. How leading organizations use big data and analytics to innovate. Strategy & Leadership. Vol. 43 Iss 5. Pp. 32 - 39. http://dx.doi.org/10.1108/SL-06-2015-0054. Accessed: 28 October 2015

technical application, to find useful correlations of data, opens opportunities for organizations, and should avoid threats for data owners.[211] This area of conflict has to be balanced by participants and regulatory authorities.

Focusing on **automation & integration**, e.g. machine learning, in the opposite with a view on emotional aspects (influencing factor) on decision-making may explains a theory, which will link both ideas on a similar process. As Hillel Einhorn shows, that the area of learning is the focal point for considering the relative merits of psychological versus economic explanations of choice behavior. Some economists have argued that although one does not act „rationally" all the time, one will learn the optimal rule through interaction with the environment. Vague assertions about equilibrium, efficiency, and evolutionary concepts are advanced to bolster this argument. Therefore, study of how people learn from experience is important on the relative merits of psychological and economical choice theories.[212] A further developed view on machine learning seems quite similar, because machines need only the procedure to „learn" precise to optimize their algorithmic model. Similar to a human learning approach over time, machines will improve their model over time and hence the quality of the decision itself will permanently increase. An important contribution to research and practice is given by V. Verboeket and H. Krikke. Their scope was to analyze the opportunities of additive manufacturing in supply chain management. The empirical research was based on a random sample of 503 articles with a scope on supply chain and additive manufacturing, with a relevance of 61 articles. As a result, the differentiation between a traditional supply chain and an additive manufactured supply chain was evident, e.g. mass-customization vs. co-customization or economies of scale vs. shared-economies.[213] Further, for automation and integration the environment changed completely, to a new reference model for digital manufacturing platforms. Digital manufacturing platforms (IIoT) uses other platforms of added-value services and combine them (e.g. design, engineering, operations planning, execution). The idea is, to expand significant collaboration in an organization or in a supply chain.[214]

Referring to the "KPMG and Bitkom Research GmbH Report 2015" survey, the digitalization area of **digital customer access** is in scope of many organizations. In the sales and marketing function of organizations, customer analysis is an important key activity and in place in 65% of organizations and 25% are planning to implement a customer analysis. Customer relationship management is on a lower level, 38% already implemented this feature in their organization and 36% are planning to implement CRM.[215]

Finally, the digitalization area of **new business models** is relevant for the entire restructuring of a mature organization or to structure a startup company. The contribution of C. Zott and R. Amit is important to

[211] Yeung K., 2017. Hyper nudge: Big Data as a mode of regulation by design. Information, Communication & Society. Vol. 20. No. 1. Pp. 118 - 136. Accessed: 26.01.2017
[212] Einhorn H., 2008. Learning from experience and suboptimal rules in decision-making. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. P. 269
[213] Verboeket V. & Krikke H., 2019. Additive Manufacturing: A Game Changer in Supply Chain Design. Logistics, 3, 13. www.mdpi.com/journal /logistics. Pp. 1 - 27. Accessed: 08.08.2019
[214] Fraile F. et al, 2019. Reference Models for Digital Manufacturing Platforms. Applied Sciences. 9, 4433. Pp. 1 - 25. Accessed: 05.10.2019
[215] Erwin T. & Heidkamp P, 2015. Mit Daten Werte schaffen – Report 2015. KPMG and Bitkom Research GmbH. P. 42. Accessed: 27.12.2017

understand for redesigning the business model toward a digital environment. The shift of value chains is evident and challenging for all organizations. Key aspects are novelty (degree of business model innovation), lock-in (switching costs and incentives to stay in the system) and complementarities (value-enhancing effects).[216]

A further aspect for the new view on decision-making in the context of digitalization is the technological influence of processing power (**technology**). Never before computer processors had a higher performance in the market. This is reflected by Moore's law, that every 18 months processor performance will double. This effect is for application development very important, because it enables much more calculations in the same time than before and new applications are possible. One has simply to compare a cellular phone from the end of the last century to a current mobile phone, which is completely different. This law was defined by Gordon Moore in the year 1965 and is reliable until today.[217] In the future, some scientists think, that Moore's law will be technological antiquated, because of physical restraints.[218] But this thinking was always given, since Moore defined his law. Anyhow, all critics failed with their predictions, and Moore's law is still valid today. From a product perspective this development is quite important, because Moore's law creates planning dependability for the software industry. The independence between software and hardware organizations, needs on the one hand an intensive communication and on the other hand a robust predictability of developments, to deliver software packages in time, with a high-quality software solution matched on hardware possibilities. This procedure ensures market success and drives the development of hardware and software to the next level. Therefore, the end of Moore's law is still open today, because market requirements will push this development with innovations, driven by intensive competition. Finally, this development is for decision-making in complex situations very important, because for more complex decision models, a high processing power is the basis for the calculation of these complex models, in an appropriate time. Hence new possibilities for the discussed areas of digitalization are totally new, and will be merged into new applications and business models.

The novelty of this dissertation considers the latest developments of digitalization and the correlated impact on decision-making. The five digitalization areas enable new possibilities in decision-making. Moreover, understanding the influencing factors of digitalization, new opportunities for decision-making will be created. These influencing factors are the driver for digitalization. Technology is providing processing power for advanced decision modeling and simulation, to convert a big data quantity into a complex decision model. Digital tools are able to decide more accurate and faster with increased quality and transparency compared to a human decision. Transparency, in human decisions is not always possible, because emotions and cognitive heuristics are not able to be reported, but an algorithmic decision-based model will exhibit transparency. The trend of a digitalization on decision-making had been never in a situation like today. Routine and repeatable work is already automized since

[216] Zott C. & Amit R., 2017. Business Model Innovation: How to Create Value in a Digital World. Business Model Innovation. Vol. 9, No. 1, GfK MIR. De Gruyter Open. Accessed: 22.06.2017
[217] Tompson S. & Parthasarathy S., 06-2006. Moore's law: the future of Si microelectronics. Materials Today. Vol. 9, No. 620, Pp. 20 - 25
[218] Mann C. The End of Moore's Law. http://mprc.pku.edu.cn/courses/organization/autumn2013/paper/Moore's%20Law/The%20End%20of%20Moore's%20Law.pdf. Accessed: 27.12.2018

automation started in the last century with processors. But now, the combination of all digital applications together will create new possibilities for decision-making, because smartization of applications means a communication between machines. The trends of machine and deep learning, blockchain, distributed systems, new processors, customer requirements, availability of data and an appropriate bandwidth for integration, is the driver for these developments.

The digitalization idea of decisions wasn't lately in scope of research and business, because limitations in algorithmic models were given and this detraction of processing power opened up the space for the latest technological evolution. A general overview, what will occur in the future is shown in table 2-5 „Development Over Time of Decision-Making", the trend from human decisions in the past over all decision conditions, to an automation of decision-making in the future. The environmental conditions of decisions are important to follow up, because the range of complexity will steer the type of decisions over time. This general view contains a lot of small single processes and developments, but shows the general way into the future. This reflects also the novelty of the topic, because never before, decisions had been in scope for automation or autonomous decision-making. This was in the past always a key task for human managers, to decide in a complex environment with their habits and attitude, trying to manage complexity, with their cognitive limitations.

Development Over Time of Decision-Making *Table 2-5*

Decision Conditions	**Past**	**Today**	**Future**
Decision under Certainty	human	automated	automated
Decision under Risk	human	automation started	automated
Decision under Uncertainty	human	human	mainly automated

(author's construction)

New ideas for digital decision-making are even based on the development of distributed systems (cloud computing), to ensure the possibility for organizations to use these technological tools, independent of the organization's size. Therefore, every type of organization is able to contribute from this development, size and financial strength do not matter anymore. In the past, the need for a certain dimension of an organization was necessary to implement information technology, structured in giant and cost-intensive systems from a well-trained team. Today's view on distributed systems, enables every organization to use these tools on an appropriate level of operations, thus a new view on efficiency in organizations has occurred and digital tools are scalable for organizational requirements. As mentioned before, „it's not the big that eat the small …it's the fast that eat the slow", is an important success factor for the development of organizations. Organizational success is today completely new defined and

organizational size won't matter in the proportion than it was years and decades ago in businesses and industries.[219]

A different view of digitalization of decision-making in a business environment creates new challenges. The reason for this challenge is the complexity of decisions and the unstructured set of data to be managed. In the past, making decisions was a core task of senior managers and executives on every organizational level. Important was a good experience, a proper level of „gut feelings" and courage of the manager to make these core decisions. To process this complexity, machines and computers with their algorithmic models were not able to deliver appropriate results in the past, because of technological restrictions. Today the hardware limitations are solved, now the software-based modeling of algorithmic models creates the possibility to design models for these decisions under uncertainty. Quite often, machines had been used as decision support system, to prepare decisions up to a complete solution, but the final step was done by human interaction. Today this new approach is supported by artificial intelligence and machine learning for a complex situation of making decisions with a huge quantity of variables for business case simulations. This means technological restrictions are solved now and the models should be set up in organizations for these decisions with huge confidence into autonomous decision-making of machines within designed boundaries.

To consolidate the novelty of the dissertation's topic, various debates in the mentioned research conferences - of the author - regarding the topic of „ digitalization of decision-making in organizations" had been taken place. Every time a vital discussion at the end of the presentation, with a qualified contribution of audience to the topic digitalization of decision-making, was given. This was also for the author an important detection and contributed overall value to this dissertation. Finally, the theoretical view, of digitalization of decision-making in organizations is not analyzed today in detail and intellectual contribution to this topic is essential, either from a theoretical or from an empirical aspect.

2.2.3. Research Review of Digitalization in Supply Chain Management

The review of research in the field of supply chain management is essential, because in the recent years, the discipline of supply chain management developed in science and practice very strong. First of all, a fundamental work was edited by Tom Davis with his early view on supply chain management. A model development, structured within a useful case of the company Hewlett-Packard is explained in the paper "Effective Supply Chain Management".[220] The general assumption is the evident complexity of material flows for complicate products. The complexity is driven by uncertain processes of various suppliers, transportation options, and production deviations. These uncertainties lead to increased inventories, as an insurance against uncertainty. As a result of this study, within a best-run supply chain, inventory reductions between 25% and 50% were possible, by benchmarking the performance, controlling of uncertainty and planning changes. Understanding the interaction between suppliers, manufacturing and

[219] Jennings J. & Haughton L., 2002. It's not the BIG that eat the SMALL…it's the FAST that eat the SLOW. New York: HarperCollins Publishers Inc.
[220] Davis T., 1993. Effective Supply Chain Management. Sloan Management Review. Summer 1993. Pp. 35-46

customers will increase the performance of the supply chain. The first ideas of data use and IT support were described and analyzed.[221]

Essential technological developments in information technology facilitated the potential of supply chain models. The idea of a virtual integration of all participants within the supply chain management was academically developed and rolled out for practitioner. The integration of Internet technology and supply chain are evaluated by Gimenez and Lourenco in the paper of "E-Supply Chain Management: Review, Implications and Directions for Future Research". Key aspects of this research are:[222]

- Definition of what can be understood by e-supply chain management and e-logistics
- Determination of e-supply chain management in operations management (OM) and Logistics journals
- Identification of main topics of e-supply chain management during 1995-2003
- Identification of methodologies used in the existing literature
- Presentation of literature review of the main topics on e-supply chain management
- Identification of implications and directions for future research

The chosen research methodology had been literature review in academic journals with operations management and logistics. The objective was to collect, organize and synthesize existing knowledge of supply chain management and Internet. The classification of the articles was related to the processes proposed by Cooper and Lambert.[223] The described paper has contributed to knowledge on Supply Chain Management by analyzing e-supply chain management and e-logistics. The study has also described the impact of the Internet on several supply chain management processes. Finally, the literature review on the topic has shown that e-supply chain managements acknowledged as a significant topic in the supply chain management literature in most Operations Management and Logistics journals.[224]

An important model in the supply chain management environment is the SCOR model, Supply Chain Operations Reference. This model provides a standard description of supply chain processes, performance metrics, best practice and technology. The idea to improve supply chain management is given by the methodology of SCOR. This scientific approach is meanwhile rolled out as an industry standard for supply chain management.[225] Research for the SCOR model with related literature is available but limited. From the number of published data an interesting dominance of case studies and

[221] Davis T., 1993. Effective Supply Chain Management. Sloan Management Review. Summer 1993. P. 38
[222] Gimenez C. & Lourenco H.R., 07-2004. E-Supply Chain Management: Review, Implications and Directions for Future Research. Research Group in Business Logistics GREL-IET, Universitat Pompeu Fabra, Barcelona. https://ssrn.com/abstract=848424. Accessed: 29.12.2019
[223] Lambert D.M. & Cooper M.C., 1998. Supply Chain Management. Implementation issues an research opportunities. The International Journal of Logistics Management. Vol 9 (2). P. 1-19
[224] Gimenez C. & Lourenco H.R., 07-2004. E-Supply Chain Management: Review, Implications and Directions for Future Research. Research Group in Business Logistics GREL-IET, Universitat Pompeu Fabra, Barcelona. https://ssrn.com/abstract=848424. P. 37. Accessed: 29.12.2019
[225] Georgise F.B. & Thoben K.-D. & Seifert M., 03-2012. Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda. International Journal of Business and Management. Vol. 7, No. 6, March 2012 Accessed: 17.08.2019

conceptual approaches is significant. Questionnaire surveys are evidently under-represented in research, as listed in table 2-6 "Research Methods from SCOR model adaption".[226]

Research Methods from SCOR Model Adaption *Table 2-6*

Methods	**Number of Articles**
Case Studies (Primary & secondary)	14
Conceptual	6
Grounded theory approach (GTA)	3
Tool/model	3
Survey/Questionnaire/Empirical analysis	2

(Author's construction, based on Georgise, Thoben, Seifert) [227]

A more dedicated view on the SCOR model is given in research, e.g. for an IT case. The traditional view on supply chain management related to goods, will not limit the SCOR model itself, because this model may transfer to further applications, e.g. information technology. Hochstein and Uebernickel described a SCOR model within an IT framework to deliver significant evidence for an improvement in the IT department of the company BASF. Within this paper the analogy between traditional supply chain management and IT management is explained and analyzed in detail.[228]

Analyzing the SCOR model in a further application, a technical approach, e.g. RFID technology is worth to explain in detail. RFID technology will support the necessity to measure performance of supply chain management, based on the SCOR model. This approach will enable to execute appropriate actions for maintaining the competitiveness of supply chain management. The important criteria for effective performance measurement are: First the measurement considers overall company's activities and second the measures should also involve relevant financial, non-financial and intangible dimensions of performances. Third, the measures have to capture the reality adequately and the circumstances of the company's environment. Fourth, measures should be observable and measurable on quantitative terms, hence a further processing in algorithmic models is possible. The challenge today, there are often too many metrics and possibilities to measure in a SCOR model due to technological opportunities. The issues are, a large number of metrics makes it difficult to identify the best metric. Further on, the SCOR model does not present the proper method between performance measurement and the information system. Moreover, the possibility is given, that metrics have inter-correlated relationships. Finally, metrics cannot be measured by a data-set and need a further processing for performance measurement.[229] Applying RFID technology in supply chain processes, is utterly analyzed by researchers and

[226] Georgise F.B. & Thoben K.-D. & Seifert M., 03-2012. Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda. International Journal of Business and Management. Vol. 7, No. 6, March 2012. P. 9. Accessed: 17.08.2019

[227] Georgise F.B. & Thoben K.-D. & Seifert M., 03-2012. Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda. International Journal of Business and Management. Vol. 7, No. 6, March 2012. P. 13. Accessed: 17.08.2019

[228] Hochstein A. & Uebernickel F., 12-2006. Operations Management and IS: Using the SCOR-Model to Source Make and Deliver IS Services. Association for Information Systems Electronic Library. Americas Conference on Information Systems (AMCIS) 2006 Proceedings. Pp. 32-39 Accessed 10.10.2019

[229] Hwang G. & Han S. & Jun S. & Park J., 02-2014. Operational Performance Metrics in Manufacturing Process: Based on SCOR Model and RFID Technology. International Journal of Innovation, Management and Technology, Vol 5, No. 1, February 2014. Pp. 51. Accessed: 24.10.2019

practitioners, with a huge amount of applications.[230] RFID is supportive of tracking and tracing all entities automatically, material management, WIP, location of fixed and mobile resources, etc. Efficiency will be gained by tracking the entire manufacturing process.[231]

An important application in the supply chain environment is blockchain technology. This application is opening new opportunities to all participants of the supply chain. Korpela, Hallikas & Dahlberg analyzed the usage of blockchain technology in a supply chain environment. Their contribution to the scientific network is exposed in "Digital Supply Chain Transformation toward Blockchain Integration". As a result, blockchain technology appears capable of providing security and flexibility on a lower cost level than traditional transactions. [232] The empirical research is a case study of a consortium of companies (on a B2B level) operating in a global supply chain environment, with the goal to investigate how blockchain technology supports digital supply chain integration. The data were collected by a Finnish supply chain of 30 companies. This consortium is operating in 36 countries and the data collection took place in the period from 2014 to 2016. The main research questions had been:

1. How can digital supply chain integration accelerate?
2. How will blockchain technology support digital supply chain integration?

As a result of this empirical research, the digital supply chain integration design should consider all current requirements of a supply chain. Further outcomes are four vertical activities: 1.Transaction data, 2. Processing ledger or smart contract, 3. Storing blocks to peer-2-peer networks, 4. Managing blocks by mining experts.[233]

The research of De Vass, Shee and Miah "The effect of 'Internet of Things' on supply chain integration and performance: An organizational capability perspective" is asking to what extend "Internet of Things" can support external and internal process integration to deliver better supply chain and firm performance. The study aims to empirically investigate the perceived effect of "Internet of Things" adoption on supply chain process integration which supports supply chain performance.[234] The conceptual research framework of this study is designed on a process integration model and investigates empirically operational and financial performance of supply chain influenced by "Internet of Things".

[230] Wei K.Q. & Zheng L., Xiang Q. & Chen X., 10-2010. Applications of RFID in a SCOR-model: Driven Enterprise Production System. Industrial Engineering and Engineering Management (IE&EM), IEEE 17th International Conference. Oct. 2010. Pp. 501-505

[231] Hwang G. & Han S. & Jun S. & Park J., 02-2014. Operational Performance Metrics in Manufacturing Process: Based on SCOR Model and RFID Technology. International Journal of Innovation, Management and Technology, Vol 5, No. 1, February 2014. P. 53. Accessed: 24.10.2019

[232] Korpela K. & Hallikas J. & Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666. Pp. 4182-4191. Accessed: 15.10.2019

[233] Korpela K. & Hallikas J. & Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666. Pp. 4187. Accessed: 15.10.2019

[234] De Vass T. & Shee H. & Miah S., 2018. The effect of "Internet of Things" on supply chain integration and performance: An organizational capability perspective. Australasian Journal of Information Systems 2018, Vol. 22. Pp. 1-29

The hypotheses are formulated as follows:

H1: “Internet of Things” capability has a positive effect on supplier integration

H2: “Internet of Things” capability has a positive effect on internal integration

H3: “Internet of Things” capability has a positive effect on customer integration

The methodology with a structural equation model (SEM) based on survey data from 227 Australian retail firms exhibits significant results. “Internet of Things” capability has a positive and significant effect on internal, customer and supplier-related process integration, which improves the performance of the supply chain.

Nagy et al executed a research in 2017 with the topic “The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary”. This research has similarities to this dissertation, based on a mixed method approach and the topic itself. Apart from the similarities of both research projects, the clear distinction is the regional drift between Hungary and German speaking countries. Moreover, the detail level of this dissertation is less driven from a technical perspective of applications and more focused on the decision process itself. The methodology of the research is a mixed method approach as a questionnaire and an expert interview. The received answers from the questionnaire was in a quantity of 43 and the expert interview was limited to four interview partners. The objective of this study is to discover how Hungarian companies interpret the trend of Industry 4.0 including “Internet of Things” and which tools they use for process optimization.[235] The result of the mentioned research study is significant, organizations are applying “Internet of Things” tools in their supply chain environment and are more efficient to reach an optimized performance. In detail, inter-organizational processes are more efficient with their partners and an improved cooperation across the supply chain is significant.[236]

M.P. Valadares de Oliveira et al investigated in their paper “Supply Chain Process Collaboration and Internet Utilization: An International Perspective of Business to Business Relationships”, the relationship between Internet utilization between businesses, collaborative efforts and the supplier and customer-oriented process performance. They discuss the Internet as an important enhancer of collaboration in supply chain management. Further on, this effect is evaluated in an organization’s overall performance. Quite interesting to analyze was the designed structural equation model, with a similar background to this dissertation, to test the quality of the theoretical model itself. A key result of this study, there was a positive relation between Internet utilization with collaborative practices in

[235] Nagy J. & Olah J., et al. 2018. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary. Sustainability 2018, 10, 3491. www.mdpi.com/journal/sustainability. Accessed: 12.02.2020

[236] Nagy J. & Olah J., et al. 2018. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary. Sustainability 2018, 10, 3491. P.13. Accessed: www.mdpi.com/journal/sustainability from 12.02.2020.

business-to-business relationships. Even an improved overall performance of organizations was significantly confirmed by this study.[237]

Finally, Jamehshooran examined the relationships between business analytics in supply chain management and the performance in SCOR features. As a result, there is a significant positive relationship between business analytics and supply chain performance measured with the SCOR model.[238]

Reflecting above mentioned research studies, the concept of digitalization of supply chain management is significant, in research and practice. This dissertation will exhibit a research model and empirical design, which will contribute knowledge to this particular discipline of science.

[237] Valadares de Oliveira M.P. et al. 2011. Supply Chain Process Collaboration and Internet Utilization: An International Perspective of Business to Business Relationships. Economic and Business Review. Vol. 13 No. 4. Pp. 203 - 226
[238] Jamshshooran B.G. & Shaharoun A.M & Haron H.N., 2015. Assessing Supply Chain Performance through Applying the SCOR Model. International Journal of Supply Chain Management. Vol. 4, No.1. March 2015. Pp. 1 - 11

3. RESEARCH MODEL & METHODS, EMPIRICAL DESIGN & RESEARCH FINDINGS OF DIGIALIZATION OF DECISION-MAKING IN SUPPLY CHAIN MANAGEMENT

Research model and empirical design with related research methods will be exhibited in chapter 3. The empirical design is essential for scientific processing of research question and is the link between theoretical research including hypothesis definition and the empiric proof of the theoretical notion. Research question and hypothesis are the starting point and research methods including empirical design follow the theoretical notion and will be in total a common set for scientific elaboration. A theoretical basis for the empirical structure, Carl Popper's idea of critical rationalism is a central element. Reflecting critical rationalism, the causal models are designed as a rational reconstruction of the actual situation by applying the given theoretical framework.[239] If an adequate correlation between the variables is given, the model confirms the plausibility of the defined hypothesis. If the correlation is inadequate, the plausibility of the hypothesis will be rejected. Used methods will increase the evidence quality of the empirical part and contribute to a verification or falsification of research question and hypothesis.

3.1. Model Development of Digitalization of Decision-Making Performance in Supply Chain Management

Based on mentioned combination of theories, the definition of research question and main hypothesis is a subsequent step for an analysis of the topic and the formulation of a new model in the context of these theories and ideas, followed by an empirical model test. A general scientific model is developed to test hypothesis and underlying variables. Scientific research is systematic when it follows these steps:[240]

1. Identification of the problem
2. Relating this problem to existing theories
3. Collection of data
4. Analysis and interpretation of data
5. Drawing conclusions
6. Integration of these conclusions into the stream of knowledge.

The methodological principles of science differ depending on basic beliefs and provide propositions of reality from which approaches and methods result for research.[241] Depending on the research goal, researchers use structure discovering (exploratory) and structure testing (confirmative) research designs for their work.[242] These opposite ends of scientific research define the quantitative and the qualitative approaches of possibilities. The combination of both approaches is a mixed method approach, to use the

[239] Mayer, H., 2002. Interview und schriftliche Befragung - Entwicklung, Durchführung und Auswertung. München: Oldenbourg. P. 15
[240] Neuert, J., 2016. Lecture of Modul 7 – New Research Methods. P. 3
[241] Stier, W., 1996. Empirische Forschungsmethoden. Berlin. Springer. P. 417
[242] Kromrey, H., 2002. Empirische Sozialforschung: Modelle und Methoden der standardisierten Datenerhebung und Datenauswertung. Stuttgart. UTB.

advantages of quantitative and qualitative approaches, by avoiding the disadvantages of these methods. The used method is known as triangulation and tries to solve the conflict between quantitative and qualitative research methods for a valid scientific outcome. At the end it is a combination of different scientific research methods, e.g. a sequential exploratory method uses one research design first (qualitative) and then applies to a second method (quantitative).

3.1.1. Overall Research Question and Main Hypothesis of Decision-Making Performance in Supply Chain Management

The overall research question will ask for research object of research topic and is the central element for research. The hypothesis will be formulated, based on research question. Hypothesis deduction is based on the extraction and summarization of key aspects, relevant conceptualizations and empirical studies as already presented. The considered empirical studies did investigate the improvement of decision-making by digitalization in supply chain management. The research question is formulated as follows:

Is there a relationship between an intelligent digital setup for decision-making and the efficiency of the decision?

The main hypothesis is formulated as follows:

H0: The efficiency of decisions depends on the degree of an intelligent digital setup for decision-making.[243]

Decision rules define the structure of a decision model, how to select the best alternative, to reach maximum utility. The idea is, to compare the digital possibility against the human possibility of the analyzed decision, in a mathematical model as follows:

$$\Phi(A_a)_{digital} \rightarrow Max_a > \Phi(A_a)_{human} \rightarrow Max_a \qquad \text{Formula 3-1}$$

Explanation: The element A_a from the alternative quantity A, which maximizes the value of the preference function, as a digital result is more than the human result of the preference function. To justify (or falsify) the main hypothesis, several hypotheses are considered.

H1: The more intelligent the digital setup for decision-making of organizations, the better the efficiency of decisions.

H2: The more manual (human) procedures for decision-making of organizations, the worse is the efficiency of decisions.

The definition of the research question and the hypothesis will clarify the setup on a structured model definition. In the following chapters this definition will be done in detail and lead to the empirical proof of the model and verification or falsification of the research question and main hypothesis (H0).

[243] „H“ = “Hypothesis”

3.1.2. Research Model and Underlying Variables of Decision-Making Performance in Supply Chain Management

Taking the described topic into scientific context, the research question is asking for a relationship between an intelligent digital setup for decision-making and the efficiency of a decision. The intelligent digital setup means a "clever" customized system for an organization which enables an efficient process. The type of customizing has to respect the structure of the organization, e.g. industry, customers and the organizational setup, because every single organization has its own perfect fit into its competitive environment. A digital setup means, all procedures of an organization transferred into a digital context from a former analogue setup, either fully digital with machines or executed by a cyber-physical-system. The efficiency of the decision has to be taken into context to the origin of the decision, compared to an analogue environment. By setting up a research model, this differentiation is relevant and the significant difference of both conditions have to be evaluated for a validation of the analysis. The outcoming results might be manifold, but have to be in line with the research model, therefore not only the status of both environmental decisions types is relevant (digital or analogue) also the approach of measurement. The result analysis has to be defined in a valid scientific approach. For measurement of a qualitative improvement of decisions a lot of possibilities are given in science and practice, like balance scorecard, benchmarking, comparison of time series or Likert scale. Therefore, a more complex evaluation of efficiency increase should be based on a Likert scale. The main hypothesis of this dissertation will analyze the dependency of the efficiency of decisions and the digital setup for decision-making in organizations (H0).

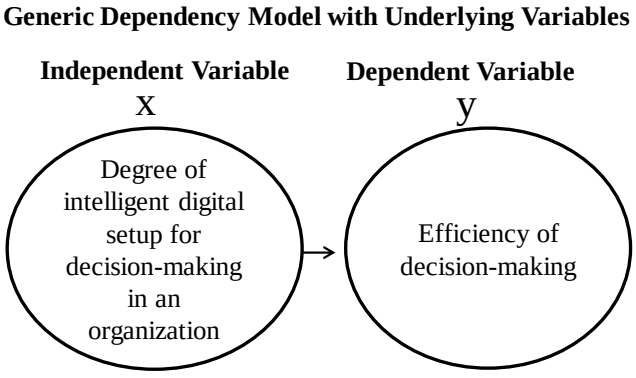

Figure 3-1 **Generic Dependency Model**

(Author's construction)

The main structure of the research model is shown in figure 3-1 „Generic Dependency Model", based on research question and main hypothesis with independent and dependent variables as a generic design. For the following model test, the variables should show a dependency, which is an evidence for verification of the hypothesis. If the dependency between independent and dependent variable is not confirmed by the model test, a rejection of the hypothesis is given. The definition of variables is:

x = Degree of intelligent digital setup for decision-making in an organization

y = f(x) = Efficiency of decision-making

The generic model is designed as a universal model for research question and main hypothesis. This model has to be seen as an open model for various applications in the wide field of digitalization of decision-making. Generic models should be seen as abstractions of application models with a general statement on a meta level. As a general starting point for designing application models with a direct linkage to empirical data, this generic model will be the scientific foundation of the hypothesis, tested in a more detailed model with an empirical structure. Moreover, a key element of a generic model should be scalability, which means flexibility and variability for application models. This relationship between generic model and application model seems quite important on a scalable basis, to define a hypothesis and then test this hypothesis empirically on a more transactional (application) model.[244] In the explained generic model the independent variable "x" is the mathematical representative for "degree of intelligent digital setup for decision-making in an organization" and the dependent variable "y" is the mathematical representative for "efficiency of decision-making". For a research model test in a real environment, there should be a more detailed definition of testing objects. For the model test, a research case is defined in the area of decisions in supply chain management, based on the SCOR model.

3.1.3. Model Test for Supply Chain Management Decision-Making Case

The decision for validation of the generic model is a supply chain management decision. The questions, based on the supply chain case of the SCOR model, is on a strategic level a case for division of work and a central process in organizations. Furthermore, is the supply chain process not an intra-organizational process, it is an intercompany-cross-border process with an interface to the external environment and thus an interaction between customers and suppliers. In today's world, the global division of work is essential for organizations. The discussed globalization aspect exhibits the relevance of the topic. The empirical case will cover all relevant digitalization areas, but not discuss the execution of customer orders in organizations on an operational level. The reflection is focusing on the strategic organizational structure and the general process functionality of customer orders as a general process flow. Managers are focused on gaining efficiency in their organization for competitive advantage. The definition and usage of digital tools should create competitive advantage for these organizations and therefore a digitalization approach for these organizations is significant for an efficient execution of customer orders. The orientation to digitalization of decision-making in this supply chain sub-process will ensure an efficient performance of the task and gain competitive advantage.

The setup of the questionnaire was designed by the postulation of equidistance, which means, the steps between the answering possibilities show the same distance to each other. The possibilities of answers are symmetric designed. The described questionnaire will evaluate the digital characteristics from a selection of a supply chain process. Based on the SCOR model the selected process steps are customer forecasts and the subsequent activities up to customer order confirmation.[245] The research model of this

[244] Clauß M., 09-2001. Generic Modeling using UML extensions for variability. Dresden University of Technology. http://www-st.inf.tu-dresden.de/mc3/varUML Accessed: 15.04.2018
[245] Bolsdorff P. & Rosenbaum R., 2007. Supply Chain Excellence. New York: AMACOM

dissertation is based on the mentioned generic model. As defined, the SCOR supply chain business chase will be analyzed on its dependency between the variables of "degree of intelligent digital setup for decision-making in an organization" and "efficiency of decisions". The definition for the independent variables is, as described in figure 3-2 „Dependency Model with Underlying Variables for a Distribution Decision" defined in the following steps. The start of the process is the data transfer of forecast data from customer to supplier, then the data transfer into the material management system to check the availability of the required goods and materials. If production is necessary, the production planning system will steer the data of the order through the process. The inventory management system supports the view on general availability for material or semi-finished goods. The last step of the analyzed process is the customer order confirmation. These independent variables will evaluate, if the process is based on a digital procedure, an analogue procedure or even a mixed process. For the dependent variable the relevant measures are cost reduction, working capital reduction and turnover growth. The evaluation of these variables is based on efficiency and will measure the performance of digitalization of decision-making in supply chain management compared to analogue decision-making. In the following empirical analysis, the performance measurement is demonstrated on descriptive statistics and a structural equation model. For a qualified measurement of the model the author decided to measure with a Likert scale. For the "x" variable all indicators are related to a process step of the SCOR model, for variable "y" the indicators for measurement are based on cost reduction, working capital reduction and turnover growth. The correlation of both variables will confirm or reject the hypothesis.

Dependency Model with Underlying Variables for Supply Chain Decision

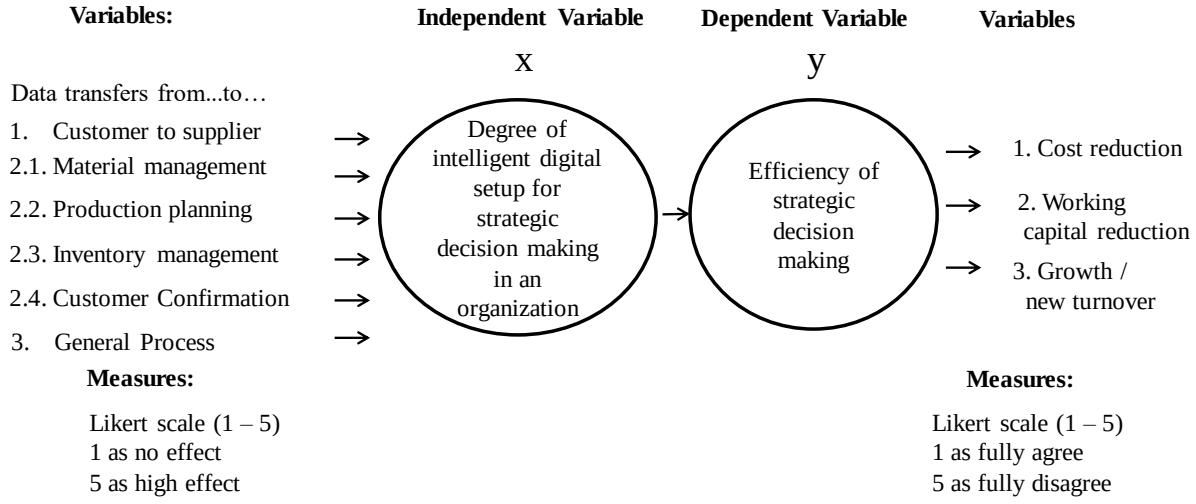

Figure 3-2 **Dependency Model with Underlying Variables for a Supply Chain Decision**

(Author's construction)

3.2. Research and Applied Methods of Decision-Making Performance in Supply Chain Management

The goal of applied research methods, is to validate the initial research question and the derived hypothesis. In the scientific community, the possibilities of research methods developed over time and are manifold today. A challenge for researchers is the selection of an appropriate method based on the underlying research question and hypothesis. This consonance should lead from a theoretical aspect of an initial research scope to empirical methods of data collection for a research and finally the corresponding analysis of the collected data.

Mixed research methods are seen controversially in context of the appropriate paradigm allocation. In the past, a dualism existed, whether only qualitative or quantitative researches should be applied. Purists of qualitative or quantitative methods point out the necessity of subjective and objective view. Some researchers even state that research methods should never be mixed.[246] Mixed methods research is formally defined as the class of research, where the researcher mixes or combines quantitative and qualitative research techniques, methods or concepts into a single study.[247] Johnson and Onwuegbuzie point out strengths and weaknesses of qualitative, quantitative and mixed research methods and resulted in a proposed „mixed methods research process model“, which allows to combine qualitative and quantitative methods in a structured way, with the view to improve the quality of the entire result.[248]

Causal modeling, also triangulation is used as research strategy. Therefore, data sets of different sources and methods are used within the empirical investigation to minimize possible bias.[249] A survey as a questionnaire had been rolled out to collect data of participants. Prior to that, a structured professionals interview was executed with relevant decision makers in organizations to analyze the relevance of the research topic. This dissertation follows the research approach for a mixed research method and applies both, qualitative and quantitative research methods in the continuing process. The mixed research design compensates the weaknesses of a single research method counterbalanced with the strengths of the other one. The mixed research method elevates research creditability and the validity of findings, based on a broader content of methods. Initially, the purpose of a qualitative research is to explore, validate and justify the theoretical measurement model of digitalization. A “structured professionals interview” with executives and senior management constituted the basis for a qualitative and quantitative research. The qualitative research has been conducted prior to the first quantitative survey, and did essentially contribute to the development of the quantitative research method. The analysis of the interview content was valuable, to rank the topic in organizations and to understand the relevance for executives and senior managers.

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[246] Johnson, R.B. & Onwuegbuzie, A.J. (2004): Mixed methods research: A research paradigm whose time has come. In: *Educational Researcher*, volume 33, issue 7. P. 14

[247] Johnson, R.B. & Onwuegbuzie, A.J. (2004): Mixed methods research: A research paradigm whose time has come. In: *Educational Researcher*, volume 33, issue 7, P. 17

[248] Johnson, R.B. & Onwuegbuzie, A.J. (2004): Mixed methods research: A research paradigm whose time has come. In: *Educational Researcher*, volume 33, issue 7. Pp. 14 - 26

[249] Brown, J. (2001). Using Surveys in Language Programs. Cambridge: Cambridge University Press. P. 228

With regard to the research objective, a quantitative empirical research was executed in a second step. A survey was chosen as plausible research method as it allows to reach the widest comparability of data.[250] Furthermore, an appropriate structuring of data is also possible by using a survey to collect data.[251] The survey was rolled out and documented with an online questionnaire. This questionnaire was the foundation of relevant data collection, to analyze the correlation degree of intelligent digital setup for decision-making in an organization and the efficiency of decision-making.

Structure of Mixed Empirical Methods *Table 3-1*

1. Qualitative & Quantitative Research	
Purpose:	Exploration, validation and justification of the topic relevance in organizations
Participants:	Sample of selected executives and senior managers
Instrument:	Structured professionals interview
Data Collection:	Personal (face to face), telephone & Skype interviews
	Data recording in spreadsheets enriched with manifold additional remarks
Data Analysis:	Limited statistical analysis, qualitative analysis of statements
2. Quantitative Research	
Purpose:	Determine data of model variables and evaluate the dimensions
Participants:	Managers and executives in distributed size and industry of organizations
Instrument:	Questionnaire in a predetermined structure
Data Collection:	Online survey – based on Google forms
Data Analysis:	Statistical analysis including descriptive statistics

(Author's construction)

Table 3-1 shows the structure of the research methods applied. The sequential structure of these methods is a step by step approach to analyze the relevance of the research question. The real challenge for measurement of qualitative items is the evaluation of values, mainly an indirect measurement of result values is possible. Therefore, a usual scaling for social and psychological science was implemented to receive measurable values, based on statistical ideas of Rensis Likert, developed in 1932 and published in his report entitled „A Technique for the Measurement of Attitudes". The method is designed, based on attitudes of interviewees for a certain object. Over the years a Likert scale found the way into the fields of research and business, thus a Likert scale is a well-known tool for a business or social based survey.[252] This psychometric scale is primarily used in questionnaires to receive the preference and the corresponding degree of agreement or even disagreement with a statement or set of statements. Likert scales is a non-comparative scaling tool and is unidimensional (measurement of only single trait) in nature. Quite often in questionnaires a 5-point-rating scale from „strongly agree" to a „strongly disagree" on the other end of the scale is used. The value in the middle is a neutral one, if the answer should not evaluate an agree or disagree status. Sometimes the scale is extended up to 7 or even 9-point-rating scale

[250] Schnell, R. & Hill, P. & Esser, E. (1999). Methoden der empirischen Sozialforschung. München: Oldenbourg. P. 319
[251] Mayring, P. (2003). Qualitative Inhaltsanalyse. Grundlagen und Techniken. Weinheim. P. 89
[252] Boone H.N. & Boone D.A., 04-2012. Analyzing Likert Data. Journal of Extension. April 2012. Volume 50. Number 2. Online. https://www.joe.org/joe/2012april/tt2.php Accessed: 04.06.2018

to get more granularity for these answers.[253] Further the idea, to set up a Likert scale with an uneven number (e.g. 5-point-rating-scale) or to set up the scale with even numbers (e.g. 4-point-rating-scale) is quite important for the structure of a rating. An uneven number of possibilities implies a neutral view on a topic from a test person. Therefore, the designer of Likert scale decides if there should be a possibility for an undecided or neutral position or if there should be an evaluation in one of both directions. In progress of Likert scales, there had been some criticism from researchers, that a 5- or 7-point-rating scale doesn't reflect a subjective quality of life. Some ideas are collected in the paper of Cummins and Gullone „Why we should not use 5-point Likert scales: The case for subjective quality of life measurement".[254] This contribution is worth to take into consideration when setting up a questionnaire with a Likert scale, and a decision for or against a Likert scale should be done consciously. After analyzing the main aspects of a Likert scale, the author decided for a 5-point-rating scale based on Likert's ideas. The setup in the empiric part of the dissertation, to get qualified input for measuring the increased quality of decisions will show the fit for the analysis. The author decided against an even number for a Likert-scale rating, because even numbers forces the respondent to make a qualified evaluation for or against an event. The respondent doesn't have the possibility to choose for a neutral position. For both empirical survey methods, the professionals interview and the online questionnaire, the author wants to offer the possibility to quote for a neutral position or position of indifference. A neutral position may have different views in both types of the surveys. The importance of a Likert scale for the structured professionals interview is given, which enables besides quantitative conclusions also qualitative statements. To solve the requirement for a more structured analysis of an interview, the tool of a Likert scale is supportive to find a solution and get a relevant analysis for these data. The characteristic of agreement or even disagreement is the value of the Likert scale, on a 5 point-scale as choice for every single interview partner. The answers are ascending natural numbers. The results of the Likert-scale items are median or modus as location parameters, and the arithmetic mean is possible to use. The definition of the Likert-scale is symmetric defined and the values handle the interval scale.

3.3. Empirical Design for Model Test of Digitalization of Decision-Making Performance in Supply Chain Management

3.3.1. Empirical Design of Survey - Layout of Structured Professional Interview

A useful research methodology for understanding the relevance of the topic, an interview is constructive. The idea to analyze subjective and socially constructed meanings expressed by those who take part in a research about the case being studied. Social constructionism assume that shared meanings and realities are dependent on people's interpretation of the events that occur around them. These meanings in qualitative research depend on social interaction, and data may more vary, because these data are more

[253] Bertram D., Likert Scales. CPSC 681 Topic Report
[254] Cummins R. & Gullone E., 2000. Why we should not use 5-point Likert scales: The case for subjective quality of life measurement. Proceedings, Second International Conference on Quality of Life in Cities. Singapore: National University of Singapore. Pp. 74-93

elastic and complex than quantitative data. To analyze and understand these data, the approach needs to be more sensitive to the characteristics and had been expressed in the interview layout.[255] To ensure a high quality of information and substantial conclusions, professionals in the analyzed area should be selected meaningful to gather this information.

The definition of an expert is not clearly described in theory and therefore the description of the method from a theoretical point of view not possible. From a practical view, gaining information for a topic, from people whose are involved deeply in this topic, will create value and will deliver qualitative content of statements for further analysis. Based on this foundation, the success of expert interviews is given with a popularity in the research community, because expert interviews deliver excellent results. [256]

The research method of a "professionals interview" is one approach to support qualitative research, as a variation of an expert interview. The term „expert" is limited and will reduce the basic population for a topic tremendously, therefore professionals should represent an adequate peer group. Compared to the method of qualitative interviews with people in general, the expert interview shows the advantage, that only adequate people are in the focus as interview candidates. This will ensure the quality of the collected data. This type of interview is based on knowledge facts and the exchange of interview participants. The interview partner and also the interviewer have to be professionals to ensure a qualitative discussion and the necessity to have a flexible interaction while the interview. Very important is, really to understand the questions in the two following directions:[257]

1. Semantic understanding: what is the meaning of the question or term in a question?
2. Pragmatic understanding: what wants the researcher or interviewer to know?

For „1. Semantic understanding", the interviewee needs clarity about the meaning of a question or term, the exact formulation and the dedicated understanding of the question. While the formulation of the question, the type of interview is important; oral or written as well as face to face or over distance.

For „2. Pragmatic understanding", the interview participant needs clarity, what the interviewer really wants to know, by asking this question. Some problems may occur, even when the semantic understanding is clear and explicit. As example: „What have you done this morning between 7 am and 8 am?" The semantic understanding is quite easy, but the real question is then, what is the background of the question. To avoid possible misunderstandings, Grice defined four basic rules for cooperative communication:[258]

1. Maximum of quantity: deliver as much information, as the interviewee needs, but not more than necessary.
2. Maximum of quality: Tell the truth. Say nothing, what's may be wrong or verified by proof.

[255] Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition. P. 568
[256] Bogner A. & Littig B. & Menz W., 2014.Interviews mit Experten – Eine praxisorientierte Einführung. Springer VS. Halle (Saale), Deutschland. P. 2
[257] Porst R., 2014. Fragebogen – Ein Arbeitsbuch. Springer VS. Halle (Saale), Deutschland. Pp. 20
[258] Porst R., 2014. Fragebogen – Ein Arbeitsbuch. Springer VS. Halle (Saale), Deutschland. P. 24

3. Maximum of relation: the interviewers contribution to discussion should support the goal of the current conversation.
4. Maximum of manner: Be precise. Avoid ambiguity and long-winded formulations and consternate statements.

The type of a structured interview enables to collect information in a structured way and to compare answers with statistical evaluations, even better than in a complete open interview. A very important element is, to provide enough space for opinions and remarks for the participant, to receive all relevant comments of the interview participant.[259] Therefore open questions had been embedded in the interview to give the opportunity for comments. Details of the structured interview are displayed in appendix 1 „Structured Professionals Interview: The Impact of Digitalization on Decision-Making". In the structure a 5-point-Likert-scale was designed to get an evaluation from low (1) to high (5). The evaluation from low to high is symmetric, hence the interview participant has the possibility to select between similar options for the answer on similar values.

The "**structured professionals interview**" was done with 21 professionals from different organizations, mainly senior managers of companies but also senior managers of non-profit organizations. The professionals are working in the field of decision-making mainly with a linkage to digitalization. The style of the interview was in direct communication but with different media, either face to face or by telephone or via Skype. The direct communication is very important, because remarks or further ideas have been caught in the discussion by the interviewer.

3.3.2. Empirical Design of Questionnaire –Supply Chain Management Decision

The empirical design for the questionnaire, is based on the theoretical ideas of Carl Popper (critical rationalism) of verification or falsification of research question and hypothesis. The detailed explanation of decisions in the supply chain management case is already done, now the description of the empirical setup for model testing will be defined. The rollout of the survey was done with an online approach to reach an appropriate quantity of qualified participants. A questionnaire as quantitative research method is an appropriate method to generate required data for further analysis. The target to get a nonvaluated picture of reality by asking involved people is a common procedure. This apporach should deliver high qualified results for further analysis and deeper examinations. The scientific approach to understand a situation from an observation perspective, without judging and bias risks, is to evaluate the data collection with an objective view.

A questionnaire is a standardized collection of questions, which are presented to people to get structured answers. A further view in the scientific context, is to use these answers for verification or falsification of the theoretical concept and scientific relations of the research model. Therefore, a questionnaire is an

[259] Sußner C. & Kuckartz U. 2005. Das Experteninterview in der Bildungsforschung. Phillips-Universität Marburg. Fachbereich Erziehungswissenschaften

important connection between a theoretical foundation and an empirical analysis.[260] The following guidelines for item formulation are relevant for a questionnaire:[261]

- Items with answering categories should be preferred in opposite to open questions, this will relieve the evaluation of the answers in a more structured scope
- When formulating the questions, the group of addressees should be in scope, mainly focussed on speech and format of answers
- Respect format conditions, e.g. layout or readability
- Consider that the first impression will motivate the respondent to process the questionnaire with an appropriate quality
- Consider the duration of the questionnaire; the process time is driven by the target group and should be selected in an appropriate manner
- Items should be short and precise, without losing quality
- Respect a logic sequence of questions
- Items which are expected to get full agreement or disagreement of participants are inappropriate
- Items with more than one fact should be avoided

A questionnaire is not simply an empirical sequence of questions, it's a science based and systematical collection of questions. Very important is the qualitative and quantitative conformity of the questionnaire with the scientific research approach. The quantitative conformity of the questionnaire with the research objective is the complete operationalization of all hypothesis and variables of the research model. The qualitative conformity is the adequate content of the questionnaire with the research objective and its hypothesis including all variables. The formulation of questions and the categories of answers have to be designed to collect data in a reliable and valid method.[262] The interview partners have to fulfill the following requirements for answering the questionnaire on a qualitative level:[263]

- Understand the question (semantic and pragmatic understanding)
- Retrieve the relevant information out of the memory for the content of the question
- Form an opinion, based on the retrieved information
- Transform the opinion into a format for the answer
- Edit the „internal" judgement into the format for the answer

The questionnaire online form was set up in a strucutre as shown in appendix 3 „Online Questionnaire 'Supply Chain Decision' " and desgined in a fitting structure for the research question and hypothesis. An online link to the questionnaire had been open for a certain period of time. The link and QR code of

[260] Porst R., 1996. Fragebogenerstellung. In: Goebl/Nelde/Stary/Wölck Hrsg. P. 737-744 aus Buch Fragebogen (P.16). P. 738
[261] Bortz J. & Döring N., 26. Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler. 4 Auflage. Berlin. Springer Verlag. P. 254
[262] Porst R., 2014. Fragebogen – Ein Arbeitsbuch. Springer VS. Halle (Saale), Deutschland. Pp. 16
[263] Porst R., 2014. Fragebogen – Ein Arbeitsbuch. Springer VS. Halle (Saale), Deutschland. P. 19

the questionnaire is still accessible and shown in appendix 4 „Link & QR Code to Online Questionnaire“.[264] The following structure was given in the online survey:

- Page 1: Explanation of the case for the questionnaire to create a common understanding
- Page 2: General questions, as personal and organizational items
- Page 3 to 5: Questions to evaluate the independent variables x_1 to x_3 – supply chain data flow
- Page 6: Questions to evaluate the dependent variables y_0 to y_2 – goals and achievements
- Page 7: General closing of the questionnaire

Describing the item structure, based on a 5-point-Likert-scale, the participants had to answer, if this process step in their company is done manual (1) or digital (5). The setup of the questionnaire was designed by the postulation of equidistance, which means, the steps between the answering possibilities show the same distance to each other. The possibilities of answers are symmetric designed (manual - 1, more manual - 2, balanced - 3, more digital - 4, digital - 5). The SCOR model describes the type of interaction between suppliers and customers, as shown in figure 1-4. For the empirical part of the dissertation, only the sourcing part is relevant. The process starts with customer demand forecast, then availability of products, production, inventory and finally customer order confirmation.

- „How does your customer deliver forecast data for the supply process? (x_1)“
- „How are the data transferred into the Material Management System? ($x_{2.1}$)“
- „How are the data transferred into the Production Planning System? ($x_{2.2}$)“
- „How are the data transferred into the Inventory Management System? ($x_{2.3}$)“
- „Do you confirm automatically the customer order to your customer, after the above described steps? ($x_{2.4}$)“
- „Overall evaluation of the entire process (x_3)”

In the second part of the questionnaire the digital characteristics of the process and the type of data flow will be asked (“a-section”), which means a 1-rating on the Likert scale for a manual process and a 5-rating for a digital process. The “b-section” of questions will ask in general for the decision type, choosing a 1-rating on the Likert scale for a decision which is completely automated (autonomous by cyber-systems) or 5-rating on the Likert scale if a decision support process is given, as shown in table 3-2. Understanding the distinction of the question items of „a-section“-questions between „Manual“ and „Digital“ a definition for the questionnaire is necessary. „Digital“ means that data processing will be done automatically without human interaction. „Manual“ means, that human interaction is necessary to process data further through the workflow. If the process consists of both elements, the participant had to estimate in the given categories, in a Likert scale from 1 to 5, as described above. “Decision support“ means, if a proposed result is automatically calculated, but a manual approval (human interaction) is required to finalize the process step. „Decision automated“ means a decision is made by a machine without further manual or human interaction.

[264] Hoßfeld S., 2016. Der Einfluss der Digitalisierung auf Entscheidungen in Organisationen. Online Survey. https://docs.google.com/forms/d/e/1FAIpQLSeZ8sSKWUn6bKdKZ9-yp6mwadEpUbGx1t_FhZbUj0FzkBRDEg/viewform?c=0&w=1. Accessed: 06.06.2018

Likert Scale for Independent Variable x for a-, b- & d-Section-Questions *Table 3-2*

a.	**Manual**	**More Manual**	**Balanced**	**More Digital**	**Digital**
	1	2	3	4	5
b.	**Decision Support**	**More Decision Support**	**Balanced**	**More Autom. Decision**	**Automated Decision**
	1	2	3	4	5
d.	**Easy**	**Partly Easy**	**Undecided**	**Partly Difficult**	**Difficult**
	1	2	3	4	5

(Author's construction)

„C-section" and „d-section" questions are a more general type of questions and are asking for the questionnaire structure itself to enrich the quality of the questionnaire and to test the understanding of the respondents. „c-section" questions are open questions with space for remarks to a- & b-section questions for each question. To increase the quality of the answer for an evaluation of the question itself, it was asked if the question had been difficult. A 1-rating on the Likert scale stands for an easy answer (high quality) and a 5-rating on the Likert scale is a difficult answer (disputable quality).

In the following flow chart (figure 3-3), the detailed process with all independent variables is defined. Starting with the customer forecast, as an external event, the process will flow into the organization's environment and is becoming an internal process, which means a higher level of control for the next steps are possible. The availability of the requested products will be checked, if they are available from stock. If the product is not available, the production planning and the sourcing process of materials has to be steered, either manual or digital. To finalize this process, the customer order confirmation is the last step. To focus on control opportunities, the process is moving in this last step again from the internal organizational environment to the external customer environment. In this questionnaire the relevance and the proportion of digital characteristics will be analyzed. All above mentioned process steps are manual or digital possible, and need to be evaluated by each questionnaire's participant. Even important is the measurement of the digitalization degree from an outside perspective into an inside perspective. The question how digital is the interface to the customer and how digital is the internal process seems quite important. The expectation, the interface to the customer is not on a highly automated level today, is an assumption and the internal process may demonstrate more digital characteristics.

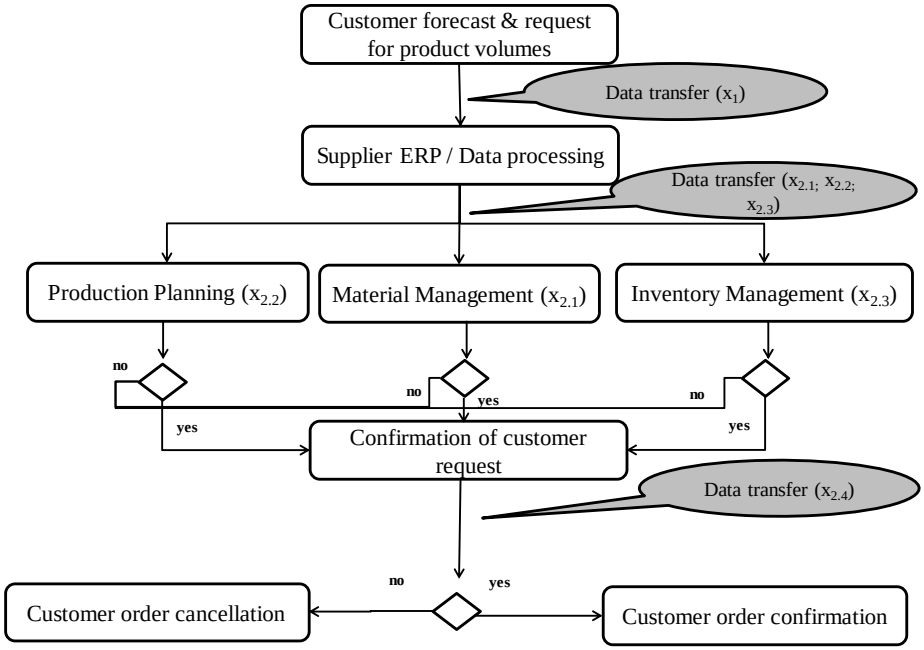


Figure 3-3 **Flow Model with Underlying Variables for a Supply Chain Decision**

(Author's construction)

In the third part of the questionnaire the goals and achievements of digitalization of decision-making had been tested, for a full picture of the research model and achieved results, namely the independent variable „y - Efficiency of decision-making". Questions had been focussed on goal setting and goal achievement for digitalization of decision-making as displayed in the table 3-3 „Likert Scale for Dependent Variable y". A 1-rating on the Likert scale was a full agreement to set and reach the discussed goal and a 5-point rating on the Likert scale was a full disagreement for this goal. Even in this case, the decision for a 5-point Likert scale was chosen, to open the space for a neutral decision, namely „Undecided". As explained in a BCG study, the digital transformation is becoming a question of life or death for most industries, but initiatives to transform toward digitalization often fail and waste an amount of money. When business rules are rewritten on a short-term basis, digital transformation has to be agile and focused on results.[265] The structure of the dependent variable y is: Digitalization Goal (y_0), Digitalization Achievement (y_1), Digitalization Overall Evaluation (y_2).

Likert Scale for Dependent Variable y *Table 3-3*

a.	Goal	**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
		1	2	3	4	5
b.	Achievement	**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
		1	2	3	4	5
c.	Overall Evaluation	**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
		1	2	3	4	5

(Author's construction)

[265] Gouvrevitch A. & Faeste L. & Baltassis E. & Marx J., 2017. Data-Driven Transformation – Accelerate at Scale Now. BCG Perspectives. 05/2017. P. 5 - 6. The Boston Consulting Group

3.4. Research Findings of Digitalization of Decision-Making Performance in Supply Chain Management

The final empirical step in this dissertation is the analysis and examination of the collected data. In this part, the defined research question and hypothesis will be confirmed or rejected. This chapter will show the significance of correlation of the designed model including further statistical evaluation.

The idea of two different empirical methods in this dissertation creates a need for an individual evaluation of each case respecting the associated empirical method. In the first step, a basic analysis will be given from the interview of senior managers and executives to analyze the relevance of digitalization. The second analysis is based on a supply chain case of the SCOR model, to analyze the intensity of digitalization in organizations, as a survey and rolled out as an online questionnaire. For this online questionnaire, different statistical methods had been applied, because massive data from participants had been collected and processed to generate analysis for the topic and a deeper understanding in regards of the research question and therewith corresponding statistical correlations.

3.4.1. Research Findings of Structured Professionals Interview

The **strucutred professionals interview** with senior managers and executives from business and non-profit organizations had been done with 21 participants, from various industries and different job professions, to get a broad view on the topic and learn from their manifold experience. Looking on regional aspects, the main focus had been in Germany, but also neighbor countries had been selected, the United Kingdom and even Kuwait. These professionals are working in management and hence the field of decision-making is a key aspect of their working life.

The structured interview style opened the opportunity to collect and evaluate structured data from this interview with statistical tools for a more detailed and advanced analysis. Moreover, to draw conclusions from the open questions section, the qualitative aspect of these interviews had been relevant. These open questions exhibited items from participants which hadn't been in the scope of the author and hence contributed to increase the quality of the interview. Qualitative data are likely to be characterized by their richness and fullness, based on the opportunity to explore a subject in a realistic manner. These qualitative data are based on meanings expressed through words and images which means a higher complexity in analysis, in opposite to quantitative data, which expresses meanings derived from numbers. The analysis is done to use conceptualization, in opposite to quantitative approach, using diagrams and statistics.[266] Understanding these differences between qualitative and quantitative data, with the postulation of getting valid conclusions out of these interview data, a mixed approach, open and closed questions in one interview was processed.

[266] Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition. P. 569

The style of the interview had been a direct communication with different media tools. The majority of the interviews had been done face to face, but also by telephone or via digital communication over Skype. The direct communication is very important, because remarks or further ideas had been caught in the discussion by the interviewer to get qualitative data and further aspects for the content of the dissertation. The statistical analysis of the interview outcome is given in table 3-4 „Relevance of Digitalization and Digitalization of Decision-Making“. As a conclusion, all data had been necessary, the structured data for a systematical analysis as well as the unstructured data for a qualitative contribution to the dissertation's content.

Relevance of Digitalization and Digitalization of Decision-Making *Table 3-4*

Relevance	**Mean**	**Standard Deviation**	**Variance**	**Median**	**Mode**
Digitalization (general)	4,48	0,51	0,26	4	4
Digitalization (own org.)	4,19	0,75	0,56	4	4
Digital decisions (today)	2,76	0,77	0,59	3	3
Digital decisions (future)	4,52	0,51	0,26	5	5

(Author's construction, based on a Likert scale 1 (low) to 5 (high))

Question 3 „How do you evaluate the relevance of digitalization for organizations in general?“, question 5 „How do you evaluate the relevance of digitalization in your organization?“ and question 6 „How do you evaluate the relevance of digitalization of decision-making or decision support in your organization?“ of the structured professionals interview are statistically analyzed in the above-mentioned table. Underlying a 5-point-Likert scale, the topic digitalization is a strong significant topic. Digitalization in general, with a mean of 4,48 shows a significant high value, as similar as digitalization for the own organization with a mean of 4,19. The standard deviation of digitalization (general) with 0,51 is low, in contrast to digitalization (own organization), with a value of 0,75. This reflects, in general digitalization is seen as a very important topic, but the status in the own organization doesn't have the same importance. The evaluation of digitalization of decision-making in the own organization is evaluated quite different over time. The current state had been evaluated with 2,76 compared to 4,52 for the future state. This means, digitalization of decision-making will be in the future more in scope of organizations and decision-makers. This reflects the situation in organizations and the way forward to implement and improve digitalization of decision-making. The standard deviation of 0,77 (today) respective 0,51 (future) reflects the different organizations and industries with their view on digitalization. The decrease of the standard deviation shows the trend, that all organizations will move toward digitalization of decision-making, from a diverse quality today.

Relevance of Digitalization Areas by Mean *Table 3-5*

Digitalization Area	Mean of Desired State	Mean of Status Quo	Mean of Future State
Big Data	4,43	2,76	3,57
Automation	4,38	2,62	3,67
Integration	4,57	2,86	4,00
Customer	4,52	2,90	4,19
Business Models	4,00	2,62	3,52
Dig. Areas (ave.)	4,38	2,75	3,79
Standard Dev.	0,20	0,12	0,26
Variance	0,04	0,01	0,07

(Author's construction, based on a Likert scale 1 (low) to 5 (high))

Table 3-5 is analyzing the mean of digitalization areas. Focusing on standard deviation within the desired state of 0,20 the level is low, with a variance of 0,04 which means a significant value. A smaller standard deviation and variance is given for the status quo. The future state for all digitalization areas highlights an increased standard deviation and variance compared to „desired state" and „status quo", with 0,26 for standard deviation and 0,07 for variance. In total, the trend for digitalization areas is increasing from the „status quo" to the „future state" in organizations. Hence a general development toward a more intensive digitalization of decision-making is expected by senior manager and executives.

Analysis of Influencing Factors of Digitalization *Table 3-6*

Influencing Factors	Mean	Standard Deviation	Variance	Median	Mode
Emotional factors	3,19	1,03	1,06	3	3
Complexity	4,10	0,77	0,59	4	4
Response time	4,19	0,87	0,76	4	5
Technology	4,48	0,75	0,56	5	5
Organizational requirements	4,19	0,81	0,66	4	4

(Author's construction, based on a Likert scale 1 (low) to 5 (high))

In above mentioned table 3-6 influencing factors of digitalization of decision-making are evaluated, again on the basis of a 5-point-Likert scale, with 1 for low and 5 for high. The main influencing factor was evaluated with „Technology", which exhibits the technological aspect of digitalization as the key driver for the development to digital and autonomous decision-making. Understanding the historical development and Moore's law, technology is obviously the main driver for digitalization. A further important evaluation with the same mean of 4,19 „Organizational requirements" as well as „Reponse time" is evaluated. „Organizational requirements" are driven by digitalization of decision-making based

on the organizational structure, e.g. the intensity of the digital setup of an organization or the size of an organization and the possibility for an efficient digital process. On the same level “Response time“ seems to be quite important to the interview participants. Managing response time on an appropriate level, a more competitive market position is possible. This is correlated to the organizational view, because only a well-structured organization is able to respond in a fast manner. From a product perspective, faster innovation cycles, driven by shorter product life cycles are today challenges for organizations, before competition is able to launch a similar product. New techniques like design thinking and “fail fast“ concepts are able to support these requirements. With a mean of 4,10 the influencing factor “Complexity“ is also relevant evaluated, because globalization, new markets and new competition added these complexities to today‘s business rules. As an example, Metcalfe’s law is reflecting this complexity, but also the opportunity to gain an improved competitive position as an organization. The lowest evaluation was given for “Emotional factors“, which means, that beside the development of digitalization and the related autonomous decision-making, emotions remain very important in business for decision-making and won’t be affected by digitalization too strong. From the author’s view, this is an unexpected result and shows the confidence in human decision-making. This leads to the assumption, even if the majority of decisions will be transferred to digital decisions, a certain extend of decisions will remain in the hand of humans and their attitude of emotional decisions. This reflects the current technological standard of decision-making, displaying a development of an emotional intelligence aspect of digitalization. More and more parts of these remaining human decisions will be transferred to machines as soon as machines are able to simulate human behavior, moods and attitudes without mistakes. Evaluating overall the “strucutred professionals interview”, as an important start for understanding the relevance of digitalization in general and the impact of digitalization on decision-making in specific. An excellent fit of the participants was given, because even a critical view on digitalization has shown a broad picture of the topic and the relevance of cutting this topic on an appropriate level for the structure of a dissertation.

3.4.2. Research Findings of Supply Chain Decision Case as Questionnaire

The questionnaire of digitalization of decision-making in supply chain management had a high level of response with an impressive quality of answers from participants. The extraordinary attention for the topic is given, based on the view, that most participants are highly interested in the results of the questionnaire. These participants were distributed mainly in German speaking countries, because the author decided, to ensure a high quality of answers and avoiding misinterpretations, to design this questionnaire in German language. Therefore, mainly native-German speaking participants took part in this online questionnaire, but even non-native German speaking participants contributed to the excellent result of this questionnaire. The empirical core task of the dissertation was to strucutre the questionnaire, based on scientific research rules and guidelines. In this chapter the results will be analyzed on a professional statistical level to exhibit the relevance of the collected data. The extensive analysis of data will judge the falsification or verification of the research question and hypothesis including all sub hypotheses. At the end of this chapter a significant indication, if there is a relationship between the digital setup for decision-making in an organization and efficiency of decision-making, will be given.

The collected quantitative data in a raw form convey little meaning itself. Therefore, the need for processing these data to make them to useful information is necessary. Hence quantitative analysis techniques help to explore, present, describe and examine relationships and trends within these data, e.g. statistics, tables or graphs.[267]

Executing 451 requests for participation, a feedback of 104 participants for the questionnaire was realized, which means a return rate of 23%. This participation rate shows a high interest for the topic of the survey. First of all, to analyze the personal strucutre of the random sample, the following attributes are given. The age of participants ranged from 26 to 75 years, on an average of 44,5 years. Asking for the gender, a pattern with a male dominated structure in senior management positions is evident - in numbers, 82% of the answers were male, only 18% were female. Comparing this with the basic population in German organizations, the random sample is almost representing the basic population. Based on official figures with a value of 22,5% for female management, is a representative value. Focusing that the peak of female managers is given in small organizations between 1 and 10 employees with a value of 25,3%.[268] The allocation of company size is displayed in table 3-7„Organizations Structure of Participants" by revenue and employees. The distribution over different organizational sizes are more or less equally distributed and doesn't represent any clumping of size. Hence the random sample should represent the entire basic population for the online questionnaire.

Organizations Structure of Participants *Table 3-7*

Revenue Distribution	**Quantity**	**(%)**		**Employee Distribution**	**Quantity**	**(%)**
0 € to 2 mio €	9	8,7%		1 to 20 employees	10	9,6%
> 2 mio € to 10 mio €	26	25,0%		21 to 100 employees	27	26,0%
> 10 mio € to 50 mio €	16	15,4%		101 to 300 employees	10	9,6%
> 50 mio € to 200 mio €	9	8,7%		301 to 1.000 employees	18	17,3%
> 200 mio € to 1.000 mio €	24	23,1%		1001 to 10.000 employees	16	15,4%
> 1.000 mio €	20	19,2%		over 10.000 employees	23	22,1%
Total	104	100,0%		Total	104	100,0%

(Author's construction)

[267] Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition. P. 496

[268] https://de.statista.com/statistik/daten/studie/182510/umfrage/frauenanteil-in-fuehrungspositionen-nach-unternehmensgroesse/ survey from 2016 in Germany. Accessed: 21.04.2018

Referring to research model, which is represented in the questionnaire, a separation of the dependent and the independent variable is given. The independent variable „Efficiency of decision-making" is represented in the questions 9 to 11. The dependent variable „Degree of digital setup for strategic decision-making in an organization" is represented in the questions 3 to 8. For a better understanding the total questions are displayed in appendix 3 "Online Questionnaire Supply Chain Decision".

To get a general view on the topic, an evaluation of questions 8 and 11 is useful, as displayed in table 3-8. Question 8 is asking for an overall evaluation of the supply chain process and its degree of digitalization in the organization. Question 11 is asking, in general, if digitalization supports a more efficient decision process in the organization. The statistical evaluation is shown in the following table and is an evidence for a mean toward digitalization with 2,85 and 2,40 for question 8.a and 8.b and a mean of 2,48 for question 11.a. This exhibits a high value of digitalization and realization of an efficient process due to digitalization. The correlation of both questions shows even a high value with -0,47 and -0,377 for questions „8.a How do you evaluate the digitalization of your entire supply chain process overall?" and „8.b. Is the entire supply chain process a completely automated decision or a decision support process?" correlated with „11.a. Overall evaluation: have you reached by digitalization of your supply chain a more efficient decision process?" Based on the determination coefficient, the evidence of a correlation between question 8.a and 11.a is given with a value of 0,219 and between question 8.b and 11.a with a value of 0,142. These high values explain the relationship between a process orientation to digital processes and process efficiency.

Statistical Evaluation of Questions 8 & 11 *Table 3-8*

	8.a. Overall evaluation of the process - digital (5) or manual (1)	8.b. Overall evaluation of the process - automated decision (5) or decision support (1)	11.a. Overall: have you reached by digitalization a more efficient process
Mean	2,851	2,406	2,480
Standard Deviation	1,024	0,971	1,124
Variance	1,048	0,944	1,262
Median	3	2	2
Mode	2	2	2
Max	5	5	5
Correlation Coefficient (to 11.a. Overall: … efficient process)	-0,468	-0,377	
Determination Coefficient	0,219	0,142	

(Author's construction)

In the next step, on a more detailed level in the supply chain process should be analyzed to proof the research model. Every a.-section of questions 3 to 8 is asking for the degree of digitalization (1 manual to 5 digital, symmetrical distributed) as displayed in table 3-9 „Statistical Evaluation of Questions Q3.a to Q8.a - 'Degree of Digitalization' ".

Statistical Evaluation of Questions Q3.a to Q8.a - Degree of Digitalization *Table 3-9*

	3.a. Customer forecast data processing - manual (1) or digital (5)	4.a. Data transfer into material management system – manual (1) or digital (5)	5.a. Data transfer into production planning system – manual (1) or digital (5)	6.a. Data transfer into inventory management system - manual (1) or digital (5)	7.a. Data transfer for customer order confirmation -manual (1) or digital (5)	8.a. Overall evaluation of the process – manual (1) or digital (5)
Mean	2,760	2,856	3,101	3,100	3,356	2,851
Standard Deviation	1,182	1,354	1,389	1,467	1,316	1,024
Variance	1,396	1,833	1,928	2,152	1,732	1,048
Median	3	3	3	3	3	3
Mode	3	2	4	5	3	2
Max	5	5	5	5	5	5

(Author's construction)

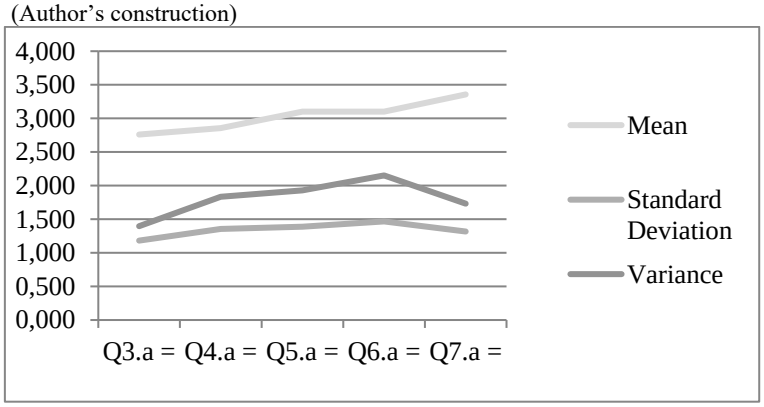


Figure 3-4 **Statistical Figure Increase over a-Questions**

(Author's construction)

For a better interpretation of the values a graph will create visualization of the analytic situation. The sequence of the questions is referring to the possible way of order processing in an organization. Understanding, the mean has the lowest value with 2,76, when the information is inbound crossing the organizational border, from the external customer into the internal workflow. This is significant, because digitized inter-organizational workflows have the highest complexity and the lowest possibility of process change. This complexity is driven by the need of synchronization of two different organizations. The supply chain function is able to offer solutions for these problems.

When the order is transferred into the organization, a digitalization of the process is more likely and it is shown by an increasing mean from 2,86 to 3,36 in the last step in the process, the customer order confirmation. This leads to the next conclusion, that the direction of the organizational border is important. The outbound process shows the highest level of digitalization, but the inbound process shows the lowest one. The perception, that these digital interfaces between customers and suppliers are not symmetric is evident. The inbound process is still more manual than the outbound process.

Every b.-section of questions 3 to 8 is asking for the decision type (1 decision support - 5 automated decision, symmetric distribution) as displayed in table 3-10 „Statistical Evaluation of Questions Q3.b to Q8.b - 'decision type' ".

Statistical Evaluation of Questions Q3.b to Q8.b - Decision Type *Table 3-10*

	3.b. Customer forecast data processing - automated decision (1) to decision support (5)	4.b. Data transfer into material management system - automated decision (1) to decision support (5)	5.b. Data transfer into production planning system - automated decision (1) to decision support (5)	6.b. Data transfer into inventory management system - automated decision (1) to decision support (5)	7.b. Data transfer for customer order confirmation - automated decision (1) to decision support (5)	8.b. Overall evaluation of the process - automated decision (1) to decision support (5)
Mean	1,930	2,515	2,673	2,710	3,010	2,406
Standard Deviation	0,967	1,289	1,338	1,373	1,353	0,971
Variance	0,934	1,660	1,789	1,885	1,830	0,944
Median	2	2	3	3	3	2
Mode	1	1	1	1	3	2
Max	4	5	5	5	5	5

(Author's construction)

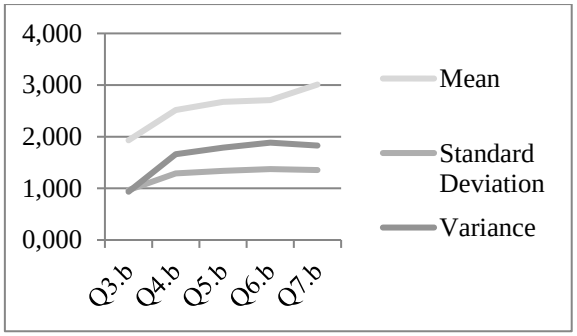


Figure 3-5 **Statistical Figure Increase over b-Questions**

(Author's construction)

The sequence of the questions is referring to the possible way of order processing in an organization. Understanding, the mean has its lowest value with 1,93 when the information is crossing the organizations border, from external to internal workflow, the digital inter-organizational workflows have the highest complexity. This complexity is driven by the need of synchronization of two organizations and may be improved by supply chain concepts. When the order is transferred into the organization, an automated decision is more likely and this is shown by an increasing mean from 2,51 to 3,01 in the last step in the process, the customer order confirmation.

Every d.-section of questions 3 to 8 is asking for the difficulty degree of the questions (1 easy – 5 difficult, symmetric distribution) and are displayed in table 3-11 „Statistical Evaluation of Questions Q3.d to Q7.d – 'difficulty degree' ".

Statistical Evaluation of Questions Q3.d to Q7.d – Difficulty Degree *Table 3-11*

	3.d. How difficult was the response to the question of data transfer of customer forecasts – easy (1) to difficult (5)	4.d. How difficult was the response to the question of data transfer into material management system – easy (1) to difficult (5)	5.d. How difficult was the response to the question of data transfer to the production system – easy (1) to difficult (5)	6.d. How difficult was the response to the question of data transfer to the inventory management – easy (1) to difficult (5)	7.d. How difficult was the response to the question of data transfer of customer order confirmation – easy (1) to difficult (5)
Mean	2,394	2,131	2,041	2,051	1,838
Standard Deviation	1,236	1,184	1,166	1,187	0,987
Variance	1,527	1,401	1,359	1,410	0,974
Median	2	2	2	2	2
Mode	1	1	1	1	1
Max	5	5	5	5	5

(Author's construction)

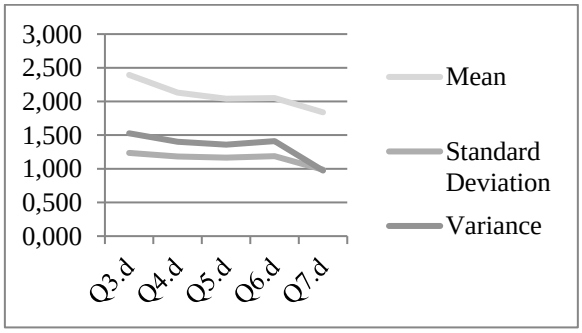


Figure 3-6 **Statistical Figure Increase over d-Questions**

(Author's construction)

The question, why is there an improvement of the mean toward easy questions in the progress of the questionnaire is a given fact, based on data, but an inscrutable fact in the analysis of the empirical data. From a psychological point of view, people first have to get warm with questions and have to feel confident with the questionnaire. Then finding their individual working mode, the assumption, that the questions are getting easier to answer. As a result, it is only an impression the questions are going to be answered easier for the participants. In reality, the questions refer absolutely to the same topic and from the author's view, the level of difficulty is the same. There is no significant difference, the mean is moving between the values of 2,39 and 1,84.

Statistical Evaluation of Questions Q9.a to Q10.c – Goals and Achievements *Table 3-12*

	9.a. Goal of cost reduction – fully agree (1) to fully disagree (5)	10.a. Achievement of cost reduction – fully agree (1) to fully disagree (5)	Deviation of Mean	9.b. Goal of working capital reduction – fully agree (1) to fully disagree (5)	10.b. Achievement of working capital reduction – fully agree (1) to fully disagree (5)	Deviation of Mean	9.c. Goal of revenue growth – fully agree (1) to fully disagree (5)	10.c. Achievement of revenue growth – fully agree (1) to fully disagree (5)	Deviation of Mean
Mean	1,871	2,677	0,806	2,202	2,874	0,672	2,594	2,906	0,312
Standard Deviation	0,945	0,912	43,1%	1,125	0,970	30,5%	1,210	1,106	12,0%
Variance	0,893	0,831		1,265	0,941		1,464	1,223	
Median	2	3		2	3		2	3	
Mode	1	2		2	3		2	3	
max	4	5		5	5		5	5	
Pearson correlation („9 -Goals“ to „10 - Achievements“)			0,358			0,378			0,494
Determination coefficient			0,128			0,143			0,244

(1 - fully agree / 5 - fully disagree - Author’s construction)

The relation between question 9 focusing on goals and question 10 focusing on achievements is an important view on the organization’s aspiration to realize defined goals. Question 9 was asking for the goals of digitalization, like cost reduction, working capital reduction or revenue increase. Then, question 10 was asking for the achievements of these goals. Consequently, an analysis for these two questions will proof the importance of the variables. Examining the mean of these questions, the evidence, that for all three sub-questions from a to c, the mean is increasing from 9 to 10, based on the 5-point Likert scale, with 1 as “fully agree”. This indicates, that the goal is set more strictly, than a realization for the goal achievement is given, hence there is a lack between goal and achievement. The strongest agreement is given with a mean of 1,871 and 2,677 for question 9.a. and 10.a., cost reduction, closely followed by the mean of question 9.b. and 10.b. working capital reduction with a value of 2,202 and 2,874. Digitalization of decision-making is more seen as a tool for efficiency increase than for revenue growth, with a mean of 2,594 and 2,906 for question 9.c and 10.c. In a further examination of the correlation between the values for questions 9 and 10, a significant correlation is given. As shown in table 3-12 ”Statistical Evaluation of Questions 9.a. to 10.c.” the high value for a-section questions (cost reduction) is given with 0,358 and for b-section questions (working capital reduction) is given with a value of 0,378. Finally, for c-section questions (revenue increase) is given a value of 0,494. The coefficient of determination is between 12,8% and 24,4%.

Analyzing the model structure itself, if the model reflects the research question with its underlying independent and dependent variables, a structural equation model (SEM) is a possibility to examine these relationships. This model is a general statistical modeling tool, which is mainly used in behavioral science. It is a combination of factor analysis and regression or path analysis. The focus of structural equation modeling is driven on theoretical constructs, which are represented by latent factors and the relationships are expressed by regression or path coefficients between these factors. SEM implies a structure for covariances between the observed variables. SEM is often visualized by a graphical path diagram and the model represents a set of matrix equations.[269]

The sub-propositions for the model are as follows:

- The degree of achievement realization depends on the degree of an intelligent digital setup for decision-making of external data (customer data and process flow)
- The degree of achievement realization depends on the degree of an intelligent digital setup for decision-making of internal data (organizational data and processes)
- The degree of achievement realization depends on the degree of an intelligent digital setup for decision-making of the general processprocess flow)
- The degree of overall process evaluation depends on the degree of an intelligent digital setup for decision-making of internal data (organizational da
- The degree of overall process evaluation depends on the degree of an intelligent digital setup for decision-making of external data (customer data and ta and processes)
- The degree of overall process evaluation depends on the degree of an intelligent digital setup for decision-making of the general process

The view of a structural equation model is the approach to examine more than one independent variable. Regression methods are limited to only one dependent variable. In the described research model of the dissertation, there is more than one independent and dependent variable in the model and therefore the SEM is supportive. The background of comparing all these dependent variables is to analyze, if there are any dependencies between these variables. The statistical model is given in the following figure, by using a path diagram and showing the structure and dependencies graphically.[270]

[269] Hox J.J. & Bechger T.M., 11-1999. An Introduction to Structural Equation Modeling. Family Science Review. 11. P. 354 – 373. https://www.researchgate.net/publication/27706391_An_Introduction_to_Structural_Equation_Modeling Accessed: 18.06.2018

[270] Backhaus K. & Erichson B. & Plinke W. & Weiber R., 2011. Multivariate Analysemethoden – Eine anwendungsorientierte Einführung. Springer Verlag. Berlin, Heidelberg. 13. Auflage. Pp. 517

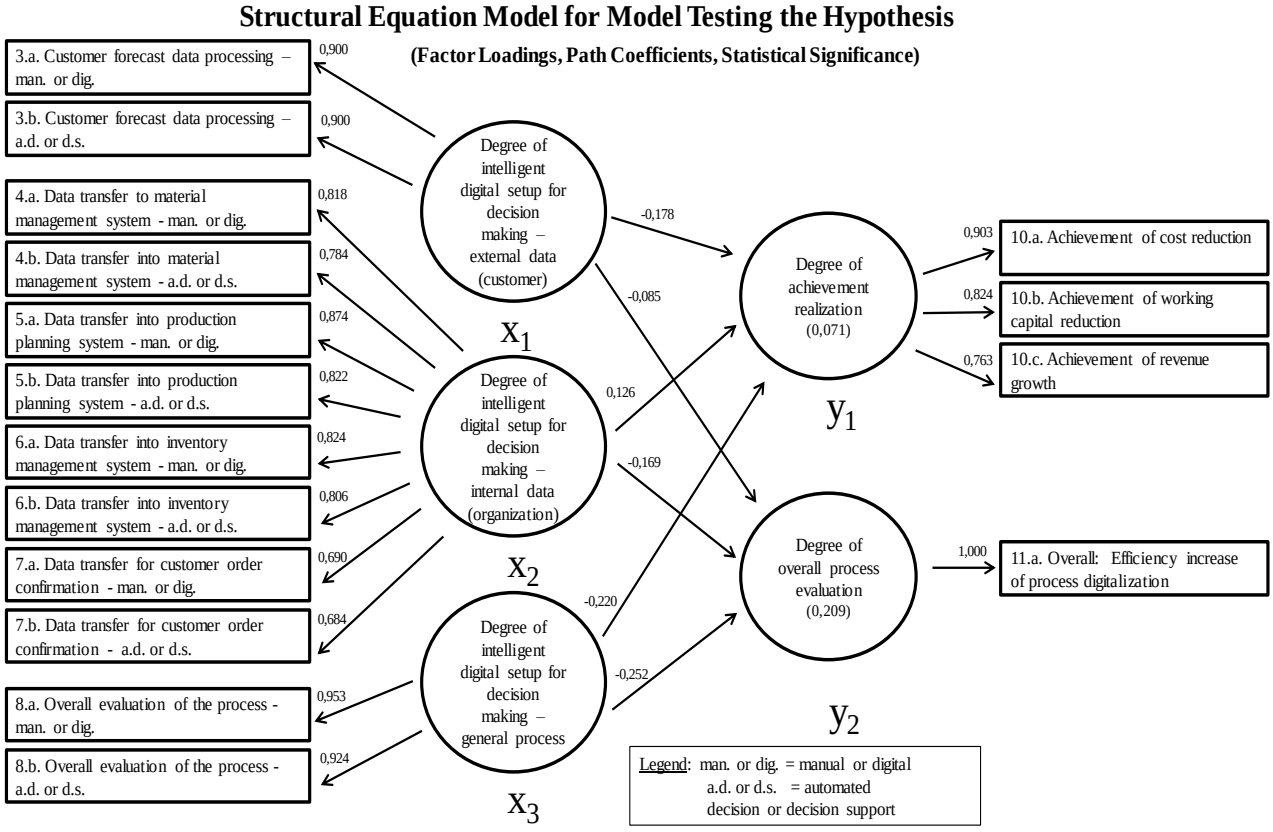


Figure 3-7 **Research Model Test with Structural Equation Model**

(Author's construction)

Analyzing the structural equation model, the values of figure 3-7 exhibit factor loading, path coefficient and coefficient of determination (R^2) of the tested variables. Questions 3.a. to 8.b. are representing the independent variables x of the supply chain case, starting from incoming data of the customer forecast, then transferred into the systems of production management, material management and inventory management, and data processing of customer order confirmation. Question 8 represents the general evaluation of the entire process. Questions 10.a. to 11.a. are representing the dependent variables y, with question 10 (y_1) as degree of achievement realization with the indicators of cost reduction, working capital reduction and revenue growth. Question 11.a (y_2) is representing the degree of the overall process evaluation. The applied procedure is PLS (Partial Least Squares), applied with the system SmartPLS.

Analyzing the coefficient of determination (R^2), the relation between x_1, x_2 and x_3 compared to y_1 exhibits a low value of 0,071, and represents a weak verifiable influence between the variables x and y_1. The coefficient of determination of x_1, x_2 and x_3 compared to y_2 shows a higher value of 0,209, and is an evidence for a medium influence of variable x to y_2. Finally, the model explains the influence of the independent variable x on the dependent variable y_1 by 7,1% and for variable y_2 by 20,9%. The effect is not significant, but a considerable correlation is given.

The independent variable x_1 (Degree of intelligent digital setup for decision making – external data) is defined by their indicators and factor loadings of 0,9000. The independent variable x_2 (Degree of intelligent digital setup for decision making – internal data) is defined by their indicators of data transfer to material management system with factor loadings of 0,818 and 0,784, data transfer into production

planning system with factor loadings of 0,874 and 0,822, data transfer into inventory management system with factor loadings of 0,824 and 0,806, and finally by data transfer for customer order confirmation with factor loadings of 0,690 and 0,684. The independent variable x_3 (Degree of intelligent digital setup for decision-making – general process) is defined by the indicator of overall evaluation of the process with a factor loading of 0,953 and 0,924. The dependent variable y_1 (Degree of achievement realization) is defined by their indicators achievement of cost reduction with factor loadings of 0,903, achievement of working capital reduction of 0,824 and achievement of revenue growth of 0,763. The dependent variable y_2 (Degree of overall process evaluation) is defined by the indicator overall efficiency increase of process digitalization with a factor loading of 1,000, because of only one single item. These factor loadings represent over all a good set of variables.

The path coefficients have a spread between the variables of x and y, which is analyzed as follows. x_1 is showing a considerable path coefficient with a value of -0,178 for dependent variable y_1, and represents a given influence on the dependent variable. The independent variable x_1 is showing a weak path coefficient with a value of -0,085 for variable y_2, a weak effect on y_2. A value of 0,126 for variable x_2 on y_1 is the only not consistent value for the analysis, referring probably due to a too small random sample. A path coefficient value of -0,169 for variable x_2 and y_2 represents a weak effect between both variables and explains a weak influence from variable x_2 on y_2. A value of -0,220 for variable x_3 and y_1 represents a medium path coefficient and explains an influence of x_3 on y_1. A further medium value of -0,252 for variable x_3 and y_2 represents a given influence of x_3 on y_2. These path coefficients show a medium level of influence of variable x on y for the tested model. A larger random sample would probably have contributed to a more significant result of the model analysis.

The statistical significance (p) as shown in appendix 5 “complementary statistical analysis”, exhibits very weak significant results, because the values are given as follows. For variable x_1, and the related variables y_1 and y_2 the values are 0,204 and 0,271 and express a weak statistical significance. For variable x_2, and the related variables y_1 and y_2 the values are 0,617 and 0,394 and express no statistical significance. For variable x_3, and the related variables y_1 and y_2 the values are 0,281 and 0,209 and express a weak statistical significance. The reason has to be seen again in the small size of the random sample, because in all likelihood for a sufficient statistical significance the sample would have to be increased up to at least 200 to 400 items. The figure similarity factor (f^2) should have a value > 0,15 to verify the statistical model fit. The highest value of the model exhibits only 0,023 between x_1 and y_1. In correspondence to statistical significance, there are no significant results and leads to a similar result.

Analysis of construct reliability and validity is given as displayed in table 3-13. The calculated figures of Cronbach’s Alpha are over all variables above 0,7, and verifies a consistent and conclusive design of the questionnaire. The key figure of composite reliability verifies the reliability of the variables, because all figures are above 0,7 for the theoretical model. The key figure of average variance extracted (AVE) is on an acceptable level, always above 0,5. The values between 0,625 and 1,000 explain the variance captured by the model versus the level of the measurement error, and verifies the model quality. Overall the model fit coefficients confirm the fit of the theorectical model and are substantiated by the empirical data set.

Construct Reliability and Validity of Structural Equation Model *Table 3-13*

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
x_1	0,765	0,895	0,810
x_2	0,914	0,930	0,625
x_3	0,866	0,937	0,881
y_1	0,776	0,870	0,692
y_2	1,000	1,000	1,000

Additional correlation analysis had been carried out of every single indicator, correlated by the independent variables x and dependent variables y. The examined statistical analysis of the survey data exhibit correlations and substantiate the hypothesis and confirm the research question positively. The technique is based on Spearman's rank-order correlation and is a nonparametric statistical correlation test. Spearman's correlation coefficient measures the strength and direction of association between two ranked variables, which are based on the research model.[271] The „Correlation Coefficient" is a statistical key figure for the range between -1 and +1. This figure represents the relationship between two ranked or numerical variables. A value of +1 is a perfect positive correlation and vice versa a -1 is a perfect negative correlation. Values between -1 and +1 represents a weaker correlation, up to a value of 0 and means the variables are perfectly independent. The statistical figure "Coefficient of Determination" of table 3-14 is a value between 0 and 1 that enables to analyze the strength of the relation between a dependent and independent variable. The coefficient represents the part of the variation of the dependent variable that can be explained statistically by the independent one. A value of 1 explains all variations of the dependent variable by the independent variable and a value of 0 means none of the variations can be explained.[272] The statistical key figure „Statistical Significance" is the likelihood of a pattern that is observed occurring by chance alone, if there was no difference in the population from that the sample was drawn.[273]

[271] https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php Accessed: 16.06.2018
[272] Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition. P. 712f
[273] Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition. P. 728

Correlation & Determination Coefficient, Statistical Significance - Question 11.a. *Table 3-14*

(based on Spearman Rho)	11.a. Overall: have you reached by digitalization a more efficient process?			
	Correlation Coefficient	Coefficient of Determination	Statistical Significance	Random Sample
3.a. Customer forecast data processing - manual or digital	-0,274	0,075	0,006	101
3.b. Customer forecast data processing - automated decision or decision support	-0,291	0,085	0,003	101
4.a. Data transfer into material management system - manual or digital	-0,421	0,177	0	99
4.b. Data transfer into material management system - automated decision or decision support	-0,315	0,099	0,001	101
5.a. Data transfer into production planning system - manual or digital	-0,408	0,166	0	99
5.b. Data transfer into production planning system - automated decision or decision support	-0,336	0,113	0,001	99
6.a. Data transfer into inventory management system - manual or digital	-0,364	0,132	0	100
6.b. Data transfer into inventory management system - automated decision or decision support	-0,282	0,080	0,004	100
7.a. Data transfer for customer order confirmation -manual or digital	-0,414	0,171	0	101
7.b. Data transfer customer order confirmation - automated decision or decision support	-0,259	0,067	0,009	101
8.a. Overall evaluation of the process – manual or digital	-0,509	0,259	0	101
8.b. Overall evaluation of the process - automated decision or decision support	-0,398	0,158	0	101

(Author's construction)

The Spearman Rho method is a useful statistical tool to evaluate the ranking order in an ordinal scale and fits perfect for the described empirical evaluation. A common Pearson correlation is not applicable based on the collected data in an ordinal scale (Likert scale). Spearman Rho method will deliver the required results for further analysis and statistical evaluation.

The dependent variable y_2„efficiency of decision-making", represented in question 11.a. „overall: have you reached by digitalization a more efficient process?" correlated with all questions of the independent variables $x_{1\text{-}3}$ „degree of intelligent digital setup for strategic decision-making in an organization" from question 3.a to 8.b., which are entirely based on the supply chain process flow. The analyzed sub process is starting from incoming data (x_1), to the operations step of material management ($x_{2.1}$), then the internal

processing in production ($x_{2.2}$) and the task of inventory management ($x_{2.3}$). As the final step in the supply chain, the analysis of outbound data in case of order confirmation to the customer ($x_{2.4}$). At the end, the overall evaluation of digitalization is covered by question 8 and variable x_3. The most relevant results of all questions related to the dependent variable "y" is question „11.a Overall: have you reached by digitalization a more efficient process in your organization?" is shown in table 3-14. This correlation is based on a general view of the topic, because question „11.a" is asking for an overall view of digitalization and not for all detailed process steps. Obviously, the correlation is evident over the entire question set, related to the described supply chain process. For a better overview an additional view, as displayed in figure 3-8 „Correlation Coefficient of Question 11.a" is given.

Starting with question 3.a, which represents variable x_1 (customer forecast) with a correlation coefficient value of -0,274. This means, 27,4% of the answers are explained by the model. With regards to content, the efficiency has increased by using an intelligent digital setup by processing incoming customer forecast data digital by 27,4%, as shown in figure 3-8 „Correlations of Question 11.a – Overall Evaluation". Further on, the correlation of variable x_1 (customer forecast) based on question 3.b „processing of customer forecast data - automated decision or decision support" compared to question 11.a is confirmed by 29,1%.

A very significant correlation coefficient is given between the variable $x_{2.1}$ represented by question 4.a „data transfer into material management system – manual or digital" and question 11.a with a value of -0,421 or 42,1%, which represents a high level of automation and shows an intelligent connection with a material management system in an organization. Linked to variable $x_{2.1}$ question 4.b „data transfer into material management system – automated decision or decision support" is correlated with question 11.a with a value of 31,5%.

Sequentially the question set 5 „production planning" represented by variable $x_{2.2}$ shows a significant correlation to question 11.a. Question 5.a „data transfer into production planning system – manual or digital" has a correlation coefficient of -0,408. This means, that the intelligent system setup for a production planning system is valid in organizations. Question 5.b „data transfer into production planning system – automated decision or decision support" represents a correlation value of 33,6% (to question 11.a), which is slightly lower than the mentioned values before, but again significant. Even here, autonomous machine procedures without manual or human interaction is done in the workflow of organizations.

Focusing on the question set 6 „inventory management" and the correlation to question 11.a, correlation is again on a significant level, but on a lower scale compared to the correlation values before. The correlation of variable $x_{2.3}$, represented by question 6.a „data transfer into inventory management system – manual or digital" is correlated with a value of 36,4% to question 11.a. The correlation of question 6.b „data transfer into inventory management system – automated or decision support" is on a lower value of 28,2%. This shows, compared to the variables before, a lower value and means, the inventory system is not as automated and integrated as other systems in an organization.

The final process step, customer order confirmation, is represented by variable $x_{2.4}$ and the question set of 7. In correlation to question 11.a, the value is for question 7.a „data transfer for customer order confirmation“ on a significant level with 41,4%. A wide spread is given compared to question 7.b „data transfer for customer order confirmation – automated decision or decision support“ with a correlation value of 25,9%. This reflects the intelligent digital setup for this particular process step, because it’s done by a digital system, but this process step is finally checked by humans, to crosscheck the outgoing document, which causes serious legal consequences between supplier and customer.

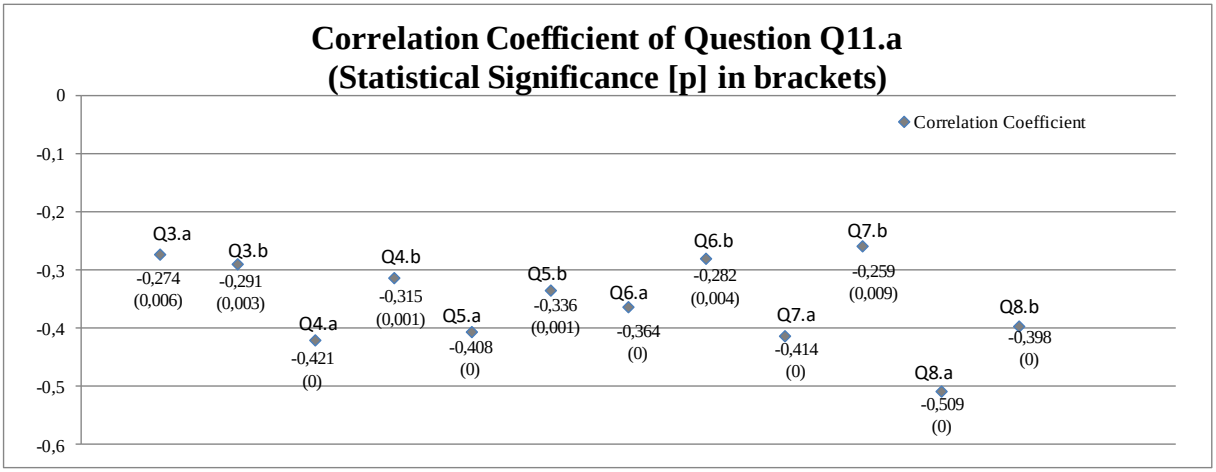


Figure 3-8 **Correlations of Question 11.a – Overall Evaluation**

(Author’s construction)

The variable x_3, representing the general question of the independent variable in question set 8 and shows a significant high correlation. Question 8.b (overall evaluation of the process – automated decision or decision support) with a value of 39,8% is highly significant. Finally, the peak of the correlation is given between the questions 11.a and 8.a „overall evaluation of the process – digital or manual“ with a correlation value of 50,9%. Both questions are referring to a general view of the supply chain digitalization and less on the detailed process steps. This view from participants shows a significant correlation of digitalization of decision-making and the efficiency of decisions. The correlation coefficient is negative, because of the question structure with the setting of the 5-point-Likert scale, from „1 – fully agree“ to „5 – fully disagree“. The coefficient of determination is between 7% and 26%, means the research model is determined with its variables for this particular set of questions. The statistical significance, as shown in the table, is always significant below 0,05. Finally, the quality of the data is high and the random error is on a low level.

Correlation & Determination Coefficient, Statistical Significance - Question 3.a & b *Table 3-15*

(based on Spearman Rho)		10.a. Achievement of cost reduction	10.b. Achievement of working capital reduction	10.c. Achievement of revenue growth
3.a. Customer forecast data processing - manual or digital	Correlation Coefficient	-0,225	-0,208	-0,129
	Coefficient of Determination	0,051	0,043	0,017
	Statistical Significance	0,025	0,039	0,202
3.b. Customer forecast data processing - automated decision or decision support	Correlation Coefficient	-0,216	-0,123	-0,207
	Coefficient of Determination	0,047	0,015	0,043
	Statistical Significance	0,032	0,229	0,04

(Author's construction)

Further significant correlations are given between the independent variable of x_1, in particular of question 3.a and dependent variable y_1, a selection of question set 10. The correlation coefficient between 3.a „customer forecast data processing – manual or digital" and question 10.a „achievement of cost reduction" is on a level of -0,225, which means 22,5% of the answers fit into the model structure. Moreover, a significant correlation between question 3.a and 10.b „achievement of working capital reduction" is given with a correlation coefficient of -0,208 or 20,8%. This is a verification of the defined theoretical model by evaluating the empirical data. A further significant correlation contributes to the hypothesis, with the correlation of question 3.b. „customer forecast data processing – automated decision or decision support" and question 10.a „achievement of cost reduction", with a coefficient of -0,216. This set of significant correlation values verifies the model, because an automation of this first step, will obviously reduce costs by digitalization and autonomous decisions of machines.

Correlation & Determination Coefficient, Statistical Significance - Question 5.a & b *Table 3-16*

(based on Spearman Rho)		9.a. Goal of cost reduction	9.b. Goal of working capital reduction	9.c. Goal of revenue growth
5.a. Data transfer into production planning system - manual or digital	Correlation Coefficient	-0,284	-0,065	-0,143
	Coefficient of Determination	0,081	0,004	0,020
	Statistical Significance	0,004	0,517	0,152
5.b. Data transfer into production planning system - automated decision or decision support	Correlation Coefficient	-0,206	0,043	-0,142
	Coefficient of Determination	0,042	0,002	0,020
	Statistical Significance	0,039	0,672	0,156

(Author's construction)

To highlight further results, variable $x_{2.2}$, respectively question 5.a."data transfer into production planning system - manual or digital" with question 9.a. „goal of cost reduction" (variable f) will be analyzed in detail. Question 5.a was asking, if the data transfer into the production planning system is manual or digital to a certain extend. This question relates to question 9.a „goal of cost reduction" on a correlation coefficient of -0,284 and a statistical significance of 0,004. An interpretation of this result is, the internal process, when external data arrived from the customer forecast are easier to process digital in an internal workflow. The production planning system is a core application of every ERP system and therefore in scope of cost reduction for every organization. All other internal processes, even the order confirmation exhibit lower values. Understanding the history for system development, the precursor-system of ERP was MRP (Material Resource Planning) as a core system for production planning and scheduling. A significant correlation is also given between the variables x_3, respective question 5.b „data transfer into production planning system – automated decision or decision support" and variable y_0, question 9.a „goal of cost reduction" with a correlation coefficient of -0,206.

Correlation & Determination Coefficient, Statistical Significance - Question 6.a & b *Table 3-17*

(based on Spearman Rho)		10.a. Achievement of cost reduction	10.b. Achievement of working capital reduction	10.c. Achievement of revenue growth
6.a. Data transfer into inventory management system - manual or digital	Correlation Coefficient	-0,158	-0,159	-0,227
	Coefficient of Determination	0,025	0,025	0,052
	Statistical Significance	0,12	0,119	0,025
6.b. Data transfer into inventory management system - automated decision or decision support	Correlation Coefficient	-0,136	-0,093	-0,211
	Coefficient of Determination	0,018	0,009	0,045
	Statistical Significance	0,18	0,36	0,037

(Author's construction)

The data of variable $x_{2.3}$ (inventory management), tested with the question set 6 will deliver significant correlations. 6.a „data transfer into inventory management system – manual or digital" in relation to question 10.c „achievement of revenue growth" displays a correlation coefficient of -0,227 and question 6.b „data transfer into inventory management system – automated decision or decision support" in relation to 10.c delivers a value of -0,211. This shows, digital inventory management is seen as a tool to increase revenue. As explained in the theoretical part, the competitor is just one click away, means having goods on stock, will enable business with customers or the supply chain.

Correlation & Determination Coefficient, Statistical Significance - Question 8.a & b *Table 3-18*

(based on Spearman Rho)		10.a. Achievement of cost reduction	10.b. Achievement of working capital reduction	10.c. Achievement of revenue growth
8.a. Overall evaluation of the process - digital or manual	Correlation Coefficient	-0,299	-0,157	-0,268
	Coefficient of Determination	0,089	0,025	0,072
	Statistical Significance	0,003	0,123	0,007
8.b. Overall evaluation of the process - automated decision or decision support	Correlation Coefficient	-0,202	-0,138	-0,213
	Coefficient of Determination	0,041	0,019	0,045
	Statistical Significance	0,045	0,175	0,034

(Author's construction)

A further remarkable correlation of variables is given with question „8.a. Overall evaluation of the process - digital or manual" and „10.a. Achievement of cost reduction". Question 8.a is asking for the general digitalization level of supply chain and question 10.a is asking for the goal of cost reduction. The general view of digitalization on supply chain exhibits a correlation coefficient to the goal of cost reduction by -0,299 and a determination coefficient of 0,089. As explained before, the general view on digitalization is correlated to cost reduction and therefore an important topic for managers, whose act for efficiency improvement of their competitive position through the goal of cost reduction. The statistical significance of 0,003 shows a significant value of a strong statement with a low error variance and a random sample of 99 valid answers of the questionnaire's participants. A similar pattern is given for question 8.b „overall evaluation of the process – automated decision or decision support" with a correlation coefficient of -0,202. Further, question „8.a. Overall evaluation of the process - digital or manual" with question „10.c. Achievement of revenue growth" shows also an evident correlation. Question 10.c is asking for the goal of revenue growth. The general view of digitalization on the supply chain in correlation to revenue growth exhibits a correlation coefficient of -0,268 and a determination coefficient of 0,072. A comparable pattern is given for question 8.b „overall evaluation of the process – automated decision or decision support" with a correlation coefficient of -0,213 in relation to question 10.c. Quite similar to the correlation before, the general view on digitalization is correlated to revenue growth as activity for managers, whose act for improvement of their competitive position by creating new paths of revenue growth and new business models to optimize the own position in the market. Attract new customers with new products and services will offer revenue growth, as explained by Porter.[274] The statistical significance of 0,007 shows a significant value of a qualitative statement with a low error variance and a random sample of 99 valid answers of questionnaire participants.

[274] Porter M.E. & Heppelmann J. E. How Smart, Connected Products Are Transforming Competition. 11-2014. Harvard Business Review. P. 5. Reprint R1411C. HBR.ORG

The analysis of all tested variables of the model are displayed in appendix 5 "Complementary Statistical Analysis" in the table „Coefficient of Correlation, Coefficient of Determination, Statistical Significance & Random Sample based on Spearman Rho".

„Kendell tau b" test was made to analyze the collected data and is displayed in appendix 5 „Complementary Statistical Analysis" as „Coefficient of Correlation, Coefficient of Determination, Statistical Significance & Random Sample based on Kendell-Tau-b". „Kendall's tau-b correlation coefficient" is a nonparametric measure of the strength and direction of association that exists between two variables measured at least on an ordinal scale. It is a proposed nonparametric alternative to the Pearson's product-moment correlation when data has failed for the assumptions of this test. Furthermore, it is considered as an alternative to the nonparametric Spearman rank-order correlation coefficient (e.g. when there is a small sample size with many tied ranks). The „Kendell tau b" test eliminates extreme values and would also fit for further analysis. If one considers variables as an independent variable and the other as a dependent variable, might consider a „Somer's d test" instead.[275]

The final analysis of the survey is a qualitative analysis on basis of questionnaire's c-section questions. From question 3 to 8 the author was asking question-by-question on the process flow for comments (from x_1 to x_3). The idea was, to generate a high qualitative picture of the situation beyond the quantitative analysis in the c-section, with open questions. These answers are delivering more content to the topic, because the additional input from participants enriched the quality of the survey and followed the mixed method's approach of this dissertation. The following remarks are split in exogenic (customer or market) and endogenic factors (organization and process). The idea is to analyze, if an organization is able to manage the challenges of digitalization itself (endogenic factors) or if there is a need for collaboration between the customer and the own organization (exogenic factors), due to increased complexity to solve these cross-organizational issues.

Exogenic and Endogenic Factors of a Digital Supply Chain Process *Table 3-19*

Exogenic Factors	**Endogenic Factors**
Some customers do not deliver forecasts	Type of organization, e.g. service industry doesn't have material flows
Forecast stability and quality is not on the level for digitalization	Effort to move toward automation is an organizational goal, new systems are projected
Post-processing of data is necessary for automated workflow	Level of organizational maturity, e.g. startup organization
Customer is driver, if process is manual or digital, e.g. customer expects a confirmation via fax	Differentiation of automation, c-articles are automated, but a-articles are manual
Less forecast data are importable into the systems	User driven effects: systems are given, but not utilized by the user

(Author's construction, based on the online questionnaire c-section „ Supply Chain Decision")

[275] https://statistics.laerd.com/spss-tutorials/kendalls-tau-b-using-spss-statistics.php Accessed: 17. 06.2018

The entire integration of systems is not given today. Either from an intra-organizational view or an inter-organizational view cross-company-border. Because of this limitation, a manual intervention into a more or less automated process is regular today. The clarity to overcome these limitations, to reach more efficiency in the process, is on the list of many organizations.

Receiving qualitative feedback from the questions related to the dependent variable y „efficiency of strategic decision-making“ was also asked in the questionnaire with qualitative feedback from participants and remarks represented by question „9.d. Do you have other objectives“ like: Customer satisfaction / Improvement of service level, Quality improvement, Supply reliability, Error prevention, Reduction of complexity, Transparency, Risk management and Improved OEE.

As an overall evaluation remains to record, the main hypothesis is verified based on the structural analysis of the survey. The research question can be confirmed, a digital setup for decision-making in an organization increases performance of decisions. This relationship is strong confirmed by questions 8 and 11, asking for digitalization effects on decision-making in general. By a more detailed analysis of the process variables, which were tested in the questions 3 to 8 for the independent variable and 9 to 10 for the dependent variable, the author would have expected a higher correlation of these variables, on a similar level like the question set of 8 and 11. This may refer to the response of the participants, that not all organizations have material processing with the corresponding supply chain. A misinterpretation of the questions can be rejected, because the level of difficulty is on an appropriate rank, as tested in the d-section of each question.

3.4.3. Summary of Research Results

The scope on decision-making, in the context of digitalization was a main guiding principle in this dissertation. Digitalization is a wide field, in practice and research, though a strict scope was necessary to focus on results. Triangulation, the usage of mixed research methods was essential to develop the results of the dissertation on a qualitative level. Starting from a qualitative and quantitative research method with a “structured professionals interview”, followed by a survey based on an online questionnaire.

Research results from all empirical studies are important for an interpretation of the topic. As foundation for the dissertation, the structured professionals interview elaborated the relevance. Therefore, the effort for further empirical data collection was appropriate, based on the importance of the topic. A qualitative feedback was given, in the interview with bright discussions around the topic digitalization mainly in relation to decision-making. The high intention of feedback from questionnaire’s participants is an indicator for the importance of the topic on management level today. Further to attract people for an interview or a questionnaire, a topic needs to be relevant in the participants view.

Analyzing the **structured professionals interview**, the **relevance of digitalization areas** seems to be quite important. The overall trend within the mean is, that the desired state exhibits highest values over

all digitalization areas, which means an aspiration to enhance the future state, organizations are willing to improve these areas within the next 24 months. There is a lack of digital readiness in the status quo of organizations today (current state). This shows the high attention of management for these focus areas in organizations. The mean shows, that all areas of digitalization are on a similar level, without any huge outlier. For digitalization of decision-making the connection to smart data (big data) is elementary, because these data are the foundation for autonomous decision-making. Algorithmic model design for exploring these data is possible today and the accuracy of data analytics is more efficient and precise done by machines or robots than humans. In combination with artificial intelligence and deep learning these models are a possible setup for completely autonomous decision-making, with a self-learning curve for permanent improvements of the model itself. This is driven by the development of technology and increased processing power. Automation and integration had been also highly rated in the interview, because these trends are being implemented in businesses today and change the way of making decisions, because machine-to-machine communication is now possible and will further increase to autonomous decisions. The inter-organizational exchange of information cross organizational borders without any human interaction will increase in the future. A main focus in the interview was the scope of digital customer access, which will tremendously change the connection between customers and organizations. All business relationships are affected by increased competition and a change in customer structures with less customer loyalty. Business models, based on the interview data didn't show the significance of digital transformation. From the author's view, this topic has not the necessary significance today, because managers are not aware of this upcoming disruptive transformation, with a completely change in the competitive landscape. This is a significant risk for the survival of organizations.

Influencing factors are the real pacemakers for digitalization. The most important influencing factor is technology. Technology is the enabler for digitalization, because today's technological opportunities allow applications, which had been never possible before. For digitalization of decision-making, these factors are a foundation, because technological borders are permanently moved toward higher processing power. The next important influencing factor, response time, is key to act effective in a competitive landscape. The need for a high speed of reaction, to gain competitive advantage, is today essential based on an extraordinary level of automation processes, ideally autonomous decision-making by machines. This is important for, e.g. shorter product life cycles and a faster innovation rate for products or services. Increased complexity in combination with new organizational challenges are drivers of digitalization on decision-making, because flat hierarchies are necessary to execute decisions very fast. This complexity is also shown in the product development process, „smartization" of products needs a new approach for development, today almost all new products are provided today with software elements. Moreover, complexity is driven by globalization, this means organizations act on a larger competitive scale compared to the past. New technology enables a global organization and global supply chain structures, which means vice versa, not using this opportunity of digitalization, organizations will fall back in their competitive position.

Analyzing **the survey of the supply chain questionnaire**, effects are more complex than expected. This general view on digitalization of decision-making and the gained efficiency is confirmed, but on a more

detailed level, this clear picture had been slightly blurred. The structural equation model delivered influences of independent variable x on dependent variable y, but on a statistical weak level. The Spearman Rho rank order correlation analysis delivered medium results to verify the hypothesis. The trend toward digitalization of decision-making is visible, but not as significant as expected. The conclusion, that cross-company-borders are still a challenge for digitalization, is a phenomenon which will be solved in the future, driven by further technological developments and requirement for increased efficiency. As soon as the data are internally in an organization, digitalization of decision-making will increase tremendously. The final step, the order confirmation to the customer was again an evidence for a high level of automation. The lack between completely autonomous decisions and decision support (manual intervention) is given, but will change in the future, when autonomous systems execute machine-to-machine communication. The trend of machine learning, based on algorithmic models, will strengthen this effect of autonomous decision-making. These relevant areas had been covered in the survey and the questionnaire had been completed by over 100 participants, with a qualitative feedback and high interest on outcoming results.

Summarizing all empirical and statistical data, the result shows medium significant relevance. The dependent variable of „efficiency of decisions“ in relation to independent variable „degree of intelligent digital setup for decision-making in an organization“ shows medium significant relevance. **A setup with different research methods for testing the model and variables was done**. Starting with a **structural equation model**, the model structure itself was tested and exhibited a medium verification of the model. The **dependency model for the supply chain case**, based on a sub-process of the SCOR model, is analyzing the data flow into the organization with the extend of digitalization for the described process. In descriptive statistics, the mean of the digitalization is steadily increasing, as shown in figure 3-4. The interpretation of this circumstance is the limited influence on customer organizations. For increasing the digitalization steps, the customer’s commitment is a requirement, which may be motivated by collaboration or benefits. In the next years, optimized organizational cross-company-border processes will increase efficiency for all involved parties. Today it is still an obstacle for the supply chain process and affects inefficiencies. Following the next step of the supply chain, when the process is steered into the own organization and under full control of the internal process owners, enables the organization to participate from efficiency gains. This means, the advantage is fully covered by the organization. Also shown in the still increasing mean over the process duration up to the customer order confirmation, the verification of hypothesis and research question is given. The return of the random sample of only 104 participants reduced the size of the sample and did not contribute to the quality of the results.

Summing up the results in context of research question and main hypothesis, a verification is given in the context of this dissertation. The developed **empirical model of triangulation** had shown the results in above mentioned chapters with all relevant details. The main research question „Is there a relationship between an intelligent digital setup for decision-making in organizations and the efficiency of the decision?“ can be confirmed positively. Consequently, the main hypothesis of the dissertation can also be confirmed, that „the efficiency of strategic decisions depends on the degree of an intelligent digital setup for decision-making in an organization. (H0) is verified.

CONCLUSIONS & SUGGESTIONS

In the final reflection of this dissertation, the author will summarize the conclusions of the examination and offer suggestions for further research projects in the area of digitalization of decision-making in supply chain management. The current importance of the topic in practice and research will trigger further research projects.

Conclusions

1. As an overall conclusion of this dissertation, the content and results contributed a valuable input to scientific research in the field of digitalization of decision-making in supply chain management. The traditional topic decision-making faces currently significant changes and will be enriched by the influence and progress of digitalization. Therefore, different aspects of decision-making are relevant and a rational behavior in decision-making is today more likely than in the past, because new decision-making procedures delivered or supported by machines and algorithms. Using in a digitized world smart data in an algorithmic decision model and then designing a conclusion for optimized decision-making, will be the path in the future for organizations to succeed with their business model. Further, the processing speed of digital solutions on a high-quality level is an advantage, because every repetition will face the same workflow without any difference, which enables robust and repeatable processes. Therefore, **better performance on decision-making will be enabled by an individual developed and optimized digital setup for decision-making in an organization**. From this follows the verification of the main hypothesis, that „The more intelligent the digital setup for decision-making of an organization, the better is the efficiency of decisions“.
2. As shown in the professional interview, managers of organizations are focussed on digitalization and its effects on decision-making. Today, the awareness is given, but a lack of execution in organizations is still existing and need to be managed by executives. This is shown, based on the question set for the relevance of digitalization. Digitalization in general shows a mean of 4,48 on a Likert scale from 1 to 5. Today the relevance in organizations is quite low with 2,76, but for the future the relevance of the topic shows a mean of 4,52. A focus on competitive advantage for organizations, leads to the conclusion, that digitalization of decision-making is a key challenge to **achieve and to remain competitiveness** in the competitive landscape.
3. Further the **quality of decision-making will increase**, because the effects of human imperfection is an obstacle in decision-making, as shown from many researchers in scientific studies. Machines will help to improve these shortcomings of human decision-making. The trend, that machines will decide autonomous, will strongly increase in the future, because the rules and requirements are set today and will enable further developments. Further technological progress will support the path of autonomous decision-making in supply chain management.
4. **Smart (big) data** enable the development of new decision-making structures. First of all, data will be created and stored for further processing in databases. In the past, events happened without the opportunity of capturing this event (e.g. taking a picture with a smart phone) as data

and storing it for further processing. Today, the collection of these events (data) in a database and using them for further processing changes the process of decision-making completely. The opportunity of using this information and designing a digital decision model (algorithmic model) is a new opportunity today. In a complete digital setup, these decision models run without human interaction, by drawing autonomous decisions. Especially in supply chain management smart data is relevant for decision-making, meanwhile data along the value chain are captured and processed for improved decision-making.

5. **Automation** itself is a key area for digitalization of decision-making in supply chain management. The opportunity to steer and control processes automatically is a perfect precondition for digitalization of decision-making in supply chain management. As shown in the mentioned empirical studies, the possibility for decision support systems is given, as a preparation for a manual decision, up to autonomous decisions, where machines will automatically make decisions without any human interaction. As an example, today are applications possible like digital twins or predictive maintenance. Based on artificial intelligence, self-learning systems will outperform human decisions, because misinterpretations, emotions or biases won't occur.
6. **Integration** is a key component for the current digital development. Beyond the technological infrastructure, mainly deployed by the technological setup of the Internet, integration of systems is a main driver. Based on integration, machine-to-machine communication is possible, without human interaction. This trend is given within organizations (intra-organizational) and over organizational boundaries (inter-organizational), e.g. like a supplier to customer relationship. As an example, an entire smart factory, without human workforce, is possible. Hence decisions are decentralized and done directly without any information or time lag. Integration is a key driver for digitalization of decision-making in supply chain management and will improve collaboration and processes.
7. **Digital customer access** is a game changer in competition. Enormous transparency of product and service offerings are given today. This new transparency, often via Internet tools and digital information, enables customers to evaluate their purchase on a transparent competitive basis. As a result, a customer will decide with increased information and raise the value of this decision. A further competitive advantage is smartization of products, having digital components which increases the value of a product tremendously or even digital products will replace real analogue products. The customer is an important part of supply chain management.
8. **New business models** will appear, which are completely based on data. The need for a typical product or service is not valid anymore. Smart services will add value to products and these new businesses are able to adopt this trend in a fast manner outperforming traditional business. Digitalization of decision-making in supply chain management will create new business models, because data management will be outsourced to specialized organizations.
9. A further conclusion is the significant relevance of **influencing factors for the effect of digitalization of decision-making in supply chain management**. The most important influencing factor for digitalization of decision-making in supply chain management is **technology**, with a mean in the mentioned survey of 4,48 on a Likert scale from 1 to 5.

Reflecting the past, the ideas of digitalization had been theoretically developed, but failed due to technological limitations quite often, e.g. artificial intelligence is a well-known example. The idea of artificial intelligence was developed in the 50ties of the last century, but never carried out any useful application since today. These days, due to latest technology with strongly increased processing power (Moore's law), artificial intelligence is, based on complex algorithmic models, rolled out in manifold applications today. As a conclusion, technology is the key driver for digitalization of decision-making in organizations. This technological development influences the layouts of the digital setup in an organization. A lot of digital tools move into organizations and optimize processes by using digital tools and features, with a significant relevance for decision-making.

10. Summing up this dissertation, a significant correlation between the degree of intelligent digital setup for decision-making in supply chain management and the efficiency of decision-making is given. The competitive situation of an organization within its industry will be completely affected and has to be on the agenda of all executives and a relevant topic for scientific researchers.

Suggestions

1. A strategical change toward digitalization of decision-making in supply chain management and therewith connected replacement of human decision-making through autonomous machine decisions, is a given challenge **for organizations**. The need to implement digital tools for decision-making in supply chain management is a fact to reach higher efficiency or increased quality, because the competitive situation in all industries requires these actions. The theoretical model with the ideas of a digital setup in correlation to improved decisions is verified by empirical studies and should encourage organizations to start moving the organization with related processes toward digitalization of decision-making in supply chain management. Due to an increased transparency and increased willingness to move away, customers tighten the competitive situation for organizations. A minimum step change should be the implementation of decision support systems, which will prepare an automated decision and will be finalized by a human being, with a strong reduction of human limitations. Above mentioned digitalization areas should be an exquisite road map to develop a digitalization strategy for decision-making in organizations. Transferring these digitalization areas into tasks, the entire organization is affected and has to respond to this new challenge. Smart data are available in every part of the organization and should be used wisefully within the digitalization strategy. Automation and integration will influence the material flow in an organization and all support processes, which is strongly reflected in supply chain management. Digital customer access is a key driver and will affect mainly the sales and marketing department, but even distribution channels and therefore the logistics department. Finally, a new digital business model for an organization will drive a completely new competitive setup. As summary, all departments and functions in an organization are affected by the digitalization of decision-making in supply chain management.
2. Decision-making is a traditional task **for managers**, since centuries executed by humans. This task will be transferred to a significant extend to machines. Managers must not remain

„restraint-guided“, to protect their core task of making decisions. Managers have to accept these new circumstances and have to pick up these new opportunities for additional methods of decision-making. Based on this development, the role of managers will change completely and the manager will not be the „lighthouse“ of knowledge and execution anymore. Managers have to steer complexity in the future, internalizing this new area of responsibility, will be the main challenge for managers and their bosses. Beyond this, managers have to implement these new developments in their organization to remain and to gain competitiveness. If this change won't succeed these organizations will struggle and may disappear from the market. The headcount of managers will be reduced in the future, because decisions will be done autonomous or will be prepared automatically. Therefore, the need for managers will shrink, but remaining managers have to build new attitudes for this new digital world. The type of decision-making will move in a completely new direction. Overall, this management challenge is not to underestimate and needs to be steered from top to down in the organization.

3. The field of decision-making moves back to the old ideas of early economists and sees the first time the opportunity of creating pure rational decision-making. The analyzed limitations of human decision-making, as described from well-known researchers will be solved and enable completely new opportunities **for researchers**. As a contest to public research, private research in this field is enormous, because many companies created a business model within this new industry. Currently the ideas for digitalization of decision-making in supply chain management, are expected to generate profit. The opportunity for startup companies to collect money in this environment is given today. Therefore, the collaboration between public and private research would contribute knowledge to this scientific field, which will accelerate the progress in this research field of digitalization of decision-making in supply chain management.
4. Developing this research further, **researchers** should focus on the level of the return amount of the random sample, because with only 104 participants, statistical results were not as meaningful as expected from the author.
5. The effect, that machines will take over decisions from humans is a very sensitive trend **for publicity**. But in today's world this trend is already implemented, e.g. chatbots, autonomous car driving and traffic systems, artificial intelligence in smart phones or cobots. Therefore, regulations have to be carried out, because the worries and concerns of publicity of unregulated autonomous machines is huge and legislation has to design rules for the new world. Governments and multinational organizations like the European Union are in the process to design rules for handling these digital trends like GDPR – General Data Protection Regulation. An autonomous decision needs transparency.
6. A future scenario for our working society will face a dramatic change, which is named as Industry 4.0, because the expected trends will be similar to the latest industrial changes like steam or electricity. In particular, digitalization of decision-making in supply chain management, will reduce jobs in organizations, because machines will deploy working with higher performance and increased quality. This social change will transfer society dramatically, because the need for highly skilled people will increase to steer these machines and the need for less skilled people will drop dramatically. From an macroeconomically perspective, all

organizations need to create a strategy toward digitalization of decision-making in supply chain management to set the direction for a competitive strategy.

7. Implications for further research: The challenge for organizations to reach readiness for the digital age is a key factor for survival and future success. This task will be for management an important aspect of their daily work to create organizations with the right answers for their own digitalization path. Mainly in the center of this idea for further research is the human aspect, because the role of employees in organizations will change completely.
8. The future of work in general will change dramatically by digitalization, because machines will widely take over tasks from human beings. In this dissertation the focus was on the process of digitalization of decision-making in supply chain management, from a human perspective to a digital perspective. The consequential next step toward the replacement of employees by machines had not been discussed. As AI and robotic systems become far more capable and committed, work will increasingly be processed without humans, perhaps achieving what John Maynard Keynes described in „Economic Possibilities for our Grandchildren“ as technological unemployment, in which technology replaces human labor faster than we discover new jobs. Keynes predicted this would only be “a temporary phase of maladjustment,” and that within a century, humankind might overcome its fundamental economic challenge and be freed from the biological necessity of working.[276]

Finally, the entire business world will change, driven by digitalization. A need for new skills is a key factor for success, like empathy and communication, critical thinking, creativity or imagination and vision. These skills are underestimated today, but will in a digital world be a competitive factor between humans and robots.[277] Understanding the new challenge of the professional world, new jobs will appear, completely different from today’s structure, e.g. computer and mathematical specialists or data analysts.[278]

[276] Wolcott R., 01-2018. How Automation Will Change Work, Purpose, and Meaning. Harvard Business Review. https://hbr.org/2018/01/how-automation-will-change-work-purpose-and-meaning?utm_content=buffer4958a&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer Accessed: 26.01.2018

[277] https://www-forbes-com.cdn.ampproject.org/c/s/www.forbes.com/sites/bernardmarr/2018/08/06/7-job-skills-of-the-future-that-ais-and-robots-cant-do-better-than-humans/amp/ Accessed: 01.10.2018

[278] https://amp-weforum-org.cdn.ampproject.org/c/amp.weforum.org/agenda/2016/01/8-jobs-every-company-will-be-hiring-for-by-2020 Accessed: 01.10.2018

REFERENCES & BIBLIOGRAPHIE

Books & Scientific Articles

1. Albrow M. & King E.,1990. Globalization, Knowledge and Society. London: SAGE
2. Ambrus A. & Greiner B. & Pathak P., 05-2009. Group versus individual decision-making: Is there a shift? https://www.sss.ias.edu/files/papers/econpaper91.pdf. Accessed: 24.01.2018
3. Ansoff H.I., 1986. Corporate Strategy. McGraw-Hill. London
4. Ansoff H.I. & McDonnell E.J. 1990. Implanting Strategic Management. Prentice Hall International (UK) Ltd, Hertfordshire
5. Ashraf N. & Camerer C.F. & Loewenstein G., 2005. Adam Smith, Behavioral Economist. Journal of Economic Perspectives—Volume 19, No. 3. Pp. 131 - 145
6. Awad H., Nassar M.O. 2009. Supply Chain Integration: Definition and Challenges. Manuscript of 28.12.2009
7. Backhaus K. & Erichson B. & Plinke W. & Weiber R., 2011. Multivariate Analysemethoden – Eine anwendungsorientierte Einführung. Springer Verlag. Berlin, Heidelberg. 13. Auflage
8. Bamberg G. & Coenenberg A. & Krapp M., 2012. Betriebswirtschaftliche Entscheidungslehre. München: Verlag Franz Vahlen
9. Bauer W. & Hämmerle M. & Schlund S. & Vocke C., 2015. Transforming to a hyper-connected society and economy – towards an "Industry 4.0". Science direct, Procedia Manufacturing 3 (2015) 417 - 424, Elsevier
10. BDI Research. 2015. Die digitale Transformation der Industrie; BDI – Bundesverband der deutschen Industrie
11. Bertram D., Likert Scales. CPSC 681 Topic Report
12. Blandford, A., 2013. Semi-structured qualitative studies. In: The Encyclopedia of Human-Computer Interaction, 2nd Ed. Aarhus, Denmark. http://discovery.ucl.ac.uk/1436174/2/semi-structured_qualitative_studies.pdf. Accessed: 02.02.2018
13. Bley S. & Kilger C, & Vogel J., 2016. Industrie 4.0 - das unbekannte Wesen. Ernst & Young. P. 8. Accessed: 03.12.2017
14. Bogner A. & Littig B. & Menz W., 2014. Interviews mit Experten – Eine praxisorientierte Einführung. Springer VS. Halle (Saale), Deutschland
15. Bolsdorff P. & Rosenbaum R., 2007. Supply Chain Excellence. New York: AMACOM
16. Boone H.N. & Boone D.A., 04-2012. Analyzing Likert Data. Journal of Extension. April 2012. Volume 50. Number 2. Online. https://www.joe.org/joe/2012april/tt2.php Accessed: 04.06.2018
17. Bopp F. 2010. Rapid Manufacturing: Zukünftige Wertschöpfungsmodelle durch generative Fertigungsverfahren. Hamburg; Diplomica Verlag

18. Bortz J. & Döring N., 2006. 26. Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler. 4 Auflage. Berlin. Springer Verlag
19. Boyanov K., 2003. John Vincent Atanasoff - The Inventor of the First Electronic Digital Computing. International Conference on Computer Systems and Technologies - CompSysTech'2003
20. Brown, J. (2001). Using Surveys in Language Programs. Cambridge: Cambridge University Press
21. Buchanan L. & O'Connell A., 01/2006. A Brief History of Decision-making. Harvard Business Review
22. Chiu C. 2014. What can crowdsourcing do for decision support? Decision Support Systems 65 (2014) 40 – 49; Elsevier
23. Cohen J. & Chesnick E.I. & Haran D., 2008. Evaluation of compound probabilities in sequential choice. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
24. Chopra S. & Meindl P., 2001. Supply Chain Management: Strategy, Planning, and Operations, Prentice-Hall, Inc. Upper Saddle River, NJ. Chapter 1
25. Cummins R. & Gullone E., 2000. Why we should not use 5-point Likert scales: The case for subjective quality of life measurement. Proceedings, Second International Conference on Quality of Life in Cities. Sinapore: National University of Singapore
26. Cyert R.M. & March J.G, 1992. A Behavioral Theory of a Firm. Cambridge and Oxford: Blackwell
27. Damme van E. & Weibull J., 1995. Equilibrium in Strategic Interaction: The Contributions of John C. Harsanyi, John F. Nash and Reinhard Selten. Scandinavian Journal of Economics 97(1)
28. Davenport D. & Libert B. & Beck M., 01-2018. Robo-Advisers Are Coming to Consulting and Corporate Strategy. Harvard Business Review. https://hbr.org/2018/01/robo-advisers-are-coming-to-consulting-and-corporate-strategy?referral=03759&cm_vc=rr_item_p..bottom Accessed: 26.01.2018
29. Davis T., 1993. Effective Supply Chain Management. Sloan Management Review. Summer 1993
30. De Vass T. & Shee H. & Miah S., 2018. The effect of "Internet of Things" on supply chain integration and performance: An organizational capability perspective. Australasian Journal of Information Systems 2018, Vol. 22
31. Drescher D., 2017. Blockchain Grundlagen – Eine Einführung in die elementaren Konzepte in 25 Schritten. Mitp Verlag. Frechen
32. Dunbrack L. et al. 03-2016. IoT and Digital Transformation: A Tale of Four Industries. IDC #US41040016, Framingham USA, Accessed: 01.11.2019
33. Dunning D., 2011. The Dunning Kruger Effect: On Being Ignorant of One's Own Ignorance. Advances in Experimental Social Psychology. Vol. 44. Elsevier Inc.
34. Einhorn H., 2008. Learning from experience and suboptimal rules in decision-making. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press

35. Erwin T. & Heidkamp P, 2015. Mit Daten Werte schaffen – Report 2015. KPMG and Bitkom Research GmbH. Accessed: 27.12.2017
36. Fayol H., 1916. Administration Industrielle et Generale. https://www.kullabs.com/classes/subjects/units/lessons/notes/note-detail/4439. Accessed: 18.04.2018
37. Fraunhofer IPA. 2017. Digitalisierung im Mittelstand – Entscheidungsgrundlagen und Handlungsempfehlungen. Stuttgart
38. Fichman R. & Dos Santos B. & Zheng Z., 06/2014. Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. MIS Quarterly Vol. 38 No. 2
39. Fischhoff B., 2008. For those condemned to study the past: Heuristics and biases in hindsight. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
40. Fraile F. et al, 2019. Reference Models for Digital Manufacturing Platforms. Applied Sciences. 9, 4433. Pp. 1 - 25. Accessed: 05.10.2019
41. Ganeshan R. & Harrison T.P., 1995. An Introduction to Supply Chain Management. Department of Management Sciences and Information Systems, Penn State University, University Park, PA. http://silmaril.smeal.psu.edu/ supply_chain_intro.html Accessed: 20.12.2019
42. Georgise F.B. & Thoben K.-D. & Seifert M., 03-2012. Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda. International Journal of Business and Management. Vol. 7, No. 6 Accessed: 17.08.2019
43. Gigerenzer G., 2001. The Adaptive Toolbox. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT
44. Gimenez C. & Lourenco H.R., 07-2004. E-Supply Chain Management: Review, Implications and Directions for Future Research. Research Group in Business Logistics GREL-IET, Universitat Pompeu Fabra, Barcelona. https://ssrn.com/abstract=848424. Accessed: 29.12.2019
45. Goes P. 07/2014. Big Data and IS Research. MIS Quarterly Vol. 38 No. 3
46. Gouvrevitch A. & Faeste L. & Baltassis E. & Marx J. Data-Driven Transformation – Accelerate at Scale Now. BCG Perspectives. 05/2017. The Boston Consulting Group
47. Grattan-Guinness I. & Bornet G., 1997. George Boole - Selected Manuscripts on Logic and its Philosophy. Birkhäuser Verlag. Basel
48. Günther J., 0-2017: Europäische Regelungen im Bereich Robotic – alles noch Science Fiction?. Der Betrieb. Nr. 12
49. Haake K. & Seiler W., 2017. Strategie-Workshop. Schäffer-Poeschel Verlag für Wirtschaft. Stuttgart
50. Hammerstein P., 2001. Evolutionary Adaption and Economic Concept of Bounded Rationality. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT
51. Hellingrath B. & Hegmanns, T. & Maaß, J.-C. & Toth M., 2007. Prozesse in Logistiknetzwerken - Supply Chain Management. Handbuch Logistik. 3rd edition, Springer Verlag Berlin / Heidelberg. Pp. 459 - 486

52. High R., 2012. The Era of Cognitive Systems: An Inside Look at IBM Watson and How it Works. 12-2012. http://johncreid.com/wp-content/uploads/2014/12/The-Era-of-Cognitive-Systems-An-Inside-Look-at-IBM-Watson-and-How-it-Works_.pdf Accessed: 06.03.2018
53. Hochstein A. & Uebernickel F., 12-2006. Operations Management and IS: Using the SCOR-Model to Source Make and Deliver IS Services. Association for Information Systems Electronic Library. Americas Conference on Information Systems (AMCIS) 2006 Proceedings. Pp. 32-39 Accessed 10.10.2019
54. Hox J.J. & Bechger T.M., 11-1999. An Introduction to Structural Equation Modeling. Family Science Review. 11. Pp. 354 – 373
55. Huberty M., 2014. Awaiting the Second Big Data Revolution: From Digital Noise to Value Creation. Springer Online. Pp. 35 - 47. Accessed: 21.12.2017
56. Hugos M., 2003. Essentials of Supply Chain Management. John Wiley & Sons, Inc., Hoboken, New Jersey
57. Hwang G. & Han S. & Jun S. & Park J., 02-2014. Operational Performance Metrics in Manufacturing Process: Based on SCOR Model and RFID Technology. International Journal of Innovation, Management and Technology, Vol 5, No. 1, February 2014. Accessed: 24.10.2019
58. Irfan D. & Xiaofei X. & Chin D. S. 2008. A SCOR Reference Model of the Supply Chain Management System in an Enterprise. The International Arab Journal of Information Technology, Vol. 5, No. 3, July 2008
59. Jamshshooran B.G. & Shaharoun A.M & Haron H.N., 2015. Assessing Supply Chain Performance through Applying the SCOR Model. International Journal of Supply Chain Management. Vol. 4, No.1. March 2015. Pp. 1 - 11
60. Jennings J. & Haughton L., 2002. It's not the BIG that eat the SMALL…it's the FAST that eat the SLOW. New York: HarperCollins Publishers Inc.
61. Johnson R.B. & Onwuegbuzie, A.J., 2004: Mixed methods research: A research paradigm whose time has come. In: *Educational Researcher*, volume 33, issue 7
62. Jonassen D.H., 04-2012. Designing for decision-making. Source: Educational Technology Research and Development, Vol. 60, No. 2 (April 2012). Pp.341-359 Published by: Springer Stable URL: http://www.jstor.org/stable/41488586. Accessed: 30.10.2017
63. Junge A.L., 2019. Digital Transformation Technologies as an Enabler for Sustainable Logistics and Supply Chain Processes – an Exploratory Framework. Brazilian Journal of Operations & Production Management 16. Pp. 462 - 472
64. Kahneman D., 2011. Thinking, Fast and Slow. UK: Penguin Random House
65. Kahneman D. & Tversky A., 1974. Judgment Under Uncertainty: Heuristics and Biases. Science, New Series, Vol. 184
66. Kahneman D. & Tversky A., 03-1979. Prospect Theory: An Analysis of Decision Under Risk. Econometrica. Mar 1979; 47, 2. Pp. 263 – 291

67. Kahneman D. & Tversky A., 2008. Subjective probability: A judgement of representativeness. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
68. Kahneman D. & Tversky A., 2008. Causal schemas in judgments under uncertainty. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
69. Kahneman D. & Tversky A., 2008. Availability: A heuristic for judging frequency and probability. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
70. Kahneman D. & Tversky A., 2008 Intuitive prediction: Biases and corrective procedures. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
71. Kahneman D. & Slovic P. & Tversky A., 2008. Judgement under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press. 24th printing
72. Kaplan J., 2016. Artificial Intelligence – What Everyone Needs to Know. New York: Oxford University Press
73. Katsuhiko S. & Michael A., 11-2004. Strategic Flexibility: Organizational Preparedness to Reverse Ineffective Strategic Decisions. Source: The Academy of Management Executive (1993-2005), Vol. 18, No. 4, Decision-Making and Firm Success (Nov., 2004). Pp. 44-59 Published by: Academy of Management Stable URL: http://www.jstor.org/stable/4166123 Accessed: 30.10.2017
74. Katz M. L. and Shapiro C., 1994. Systems Competition and Network Effects. Journal of Economic Perspectives. Volume 8, No. 2
75. Kohlöffel K.M. & August H.-J., 2012. Veränderungskonzepte und Strategische Transformation. Publicis Publishing. Erlangen
76. Korotayev A. & Tsirel S., 07-2010. A Spectral Analysis of World GDP Dynamics: Kondratieff Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis. Structure and Dynamics Journal, 4(1)
77. Korpela K. & Hallikas J. & Dahlberg T., 2017. Digital Supply Chain Transformation toward Blockchain Integration. Proceedings of the 50th Hawaii International Conference on System Science. 2017. URL: http://hdl.handle.net/10125/41666. Pp. 4182-4191. Accessed: 15.10.2019
78. Kreutzer R. & Land K.H., 2015. Digital Darwinism – Branding and Business Models in Jeopardy. Berlin. Springer Verlag
79. Kromrey, H., 2002. Empirische Sozialforschung: Modelle und Methoden der standardisierten Datenerhebung und Datenauswertung. Stuttgart. UTB
80. Krugman P., 12-1980. Scale Economies, Product Differentiation, and the Pattern of Trade. The American Economic Review. Vol. 70, No. 5 (Dec., 1980). Pp. 950-959
81. Lambert D. M. & Stock J. R. & Ellram L.M., 1998. Fundamentals of Logistics Management. Irwin/McGraw-Hill Boston, MA. Chapter 14
82. Langer E., 2008. The illusion of control. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press

83. Laux H. & Gillenkirch R. & Schenk-Mathes H., 2014. Entscheidungstheorie. Berlin; Heidelberg: Springer Verlag
84. Lee H.L. & Padmanabhan V. & Whang S. 1997. The Bullwhip Effect in Supply Chains. Sloan Management Review. Spring 1997. Pp. 93 - 101
85. Lee J. & Kao H. & Yang S., 2014. Service innovation and smart analytics for Industry 4.0 and big data Environment. Science direct, Procedia CIRP 16 (2014) 3 - 8: Elsevier
86. Levin J. & Milgrom P., 2004. Introduction to Choice Theory. http://web.stanford.edu/~jdlevin/Econ%20202/Choice%20Theory.pdf. Accessed: 15.03.2016
87. Levy M., Grewal D. 2000. Supply Chain Management in a Networked Economy. Journal of Retailing. Vol. 76 (4)
88. Lin F.& Huang S. & Lin S. 2002. Effects of Information Sharing on Supply Chain Performance in Electronic Commerce. IEEE Transactions on Engineering Management, vol. 49, no. 3
89. Mann C. The End of Moore's Law. http://mprc.pku.edu.cn/courses/organization/autumn2013/paper/ Moore's%20Law/The%20End%20of%20Moore's%20Law.pdf. Accessed: 27.12.2018
90. March J. & Simon H.A., 1997. Organizations. Cambridge and Oxford: Blackwell
91. Marr B., 2017. Data Strategy – How to Profit from a World of Big Data, Analytics and the Internet of Things. London. Kogan
92. Marshall A. & Mueck S. & Shockley R., 2015. How leading organizations use big data and analytics to innovate. Strategy & Leadership. Vol. 43 Iss 5. Pp. 32 - 39. Accessed: 28.10.2015
93. Mayer, H., 2002. Interview und schriftliche Befragung - Entwicklung, Durchführung und Auswertung. München: Oldenbourg
94. Mayring, P., 2003. Qualitative Inhaltsanalyse. Grundlagen und Techniken. Weinheim.
95. McCarthy J., 1956. Definition of Artificial Intelligence. Conference at Dartmouth college. https://www.artificial-solutions.com/blog/homage-to-john-mccarthy-the-father-of-artificial-intelligence Accessed: 14.02.2018
96. Mentzer J. T. & DeWitt W. & Keebler J.S. & Min S., et al. 2001. Defining Supply Chain Management. Journal of Business Logistics, Vol. 22, No. 2
97. Mill, J.S., 1874. On the Definition of Political Economy, and on the Method of Investigation Proper to It," London and Westminster Review, October 1836. Essays on Some Unsettled Questions of Political Economy, 2nd ed. London: Longmans, Green, Reader & Dyer
98. Muthusami S. & Srinivsan M., 2017. Supply Chain 4.0: Digital Transformation Disruptions and Strategies. Review of Business and Technology Research, Vol 14, No.2. 2017
99. Nagy J., Olah J., et al. 2018. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain – The Case of Hungary. Sustainability 2018, 10, 3491. Accessed: 12.02.2020
100. Najmi A., 01-2018. Why Your Supply Chain Needs Blockchain: Understanding the Technology and Its Link to Supply Chain Networks. http://data-informed.com/why-your-supply-chain-needs-blockchain-understanding-the-technology-and-its-link-to-supply-chain-

networks/?utm_campaign=
Monthly%20Newsletter&utm_source=hs_email&utm_medium=email&utm_content=60388934&_hsenc=p2ANqtz-_EG-HgTRvBLUxVdVfPb7jOGNgaAVTqvBD5KmhvTA8hW28hVaIWgOtueN8jQATarRvGE8ZCLzI8vq-6yFPmCgoQnBTcqA&_hsmi=60388934. Accessed: 08.02.2018

101. Nazarko J. et al. 2016. Structural Analysis as an Instrument for Identification of Critical Drivers of Technology Development. Proceedings of 7th International Conference on Engineering, Project, and Production Management (EPPM2016). Poland. Pp. 474 - 481
102. Neumann von, J. & Morgenstern O., 2007. Theory of Games and Economic Behavior – Sixtieth Anniversary Edition. Princeton: University Press
103. Neumann von J., 07-1945. First Draft of a Report on the EDVAC. Moore School of Electrical Engineering University of Pennsylvania. https://www.wiley.com/legacy/wileychi/wang_archi/supp/appendix_a.pdf. Accessed: 15.02.2018
104. Neus A. & Buder F. & Galdino F., 2017. Are You Too Successful to Digitalize? How to Fight Innovation Blindness. Innovation Blindness / Vol. 9, No. 1. De Gruyter
105. Odlyzko A. & Tilly B., 2005. A refutation of Metcalfe's Law and a better estimate for the value of networks and network connections. March 2, 2005. Digital Technology Center, University of Minnesota, USA. Accessed: 02.04.2020
106. Oskamp S., 2008. Overconfidence in case-study judgments. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press
107. Pape U., 2015. Grundlagen der Finanzierung und Investition. De Gruyter. Oldenbourg
108. Pereira A.C. & Romero F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. Proceedings of Manufacturing Engineering Society International Conference 2017, MESIC 2017, Vigo, Spain
109. Pfohl H.-C., 2010. Logistiksysteme: Betriebswirtschaftlich Grundlagen. 8. Auflage. Springer Verlag. Berlin
110. Picot A. & Reichwald R. & Wigand R., 2001. Die grenzenlose Unternehmung. München. Gabler Verlag
111. Porst R., 2014. Fragebogen – Ein Arbeitsbuch. Springer VS. Halle (Saale), Deutschland
112. Porst R., 1996. Fragebogenerstellung. In: Goebl/Nelde/Stary/Wölck Hrsg. Pp. 737-744
113. Porter M.E. & Heppelmann J. E., 11-2014. How Smart, Connected Products Are Transforming Competition. Harvard Business Review
114. Porter M. 2004. Competitive Advantage. New York. Free Press
115. Roeser S. & Hillerbrand R. & Sandin P. & Peterson M., 2012. Handbook of Risk Theory - Epistemology, Decision Theory, Ethics, and Social Implications of Risk. Aachen, Germany. Springer Science Business Media B.V.
116. Ropohl G., 2012. Allgemeine Systemtheorie. Berlin. Deutsche Nationalbibliothek
117. Ross F.D., 2003. Introduction to e-supply chain management: engaging technology to build market-winning business partnerships. CRC Press LLC, Boca Raton, Florida

118. Ross L. & Anderson C. A., 2008. Shortcomings in the attribution process: ON the origins and maintenance of erroneous social assessments. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press

119. Ross M. & Sicoly F., 2008. Egocentric biases in availability and attribution. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press

120. Sadrieh A., 2001. Is There Evidence for an Adaptive Toolbox? In: Bounded Rationality – The Adaptive Toolbox. USA. MIT

121. Saunders M. & Lewis P. & Thornhill A., 2016. Research Methods for Business Students. Pearson Education Limited. Harlow. 7th Edition

122. Schnell, R. & Hill, P.& & Esser, E., 1999. Methoden der empirischen Sozialforschung. München: Oldenbourg.

123. Selten R. & Orland A., 12-2015. Buyer power in bilateral oligopolies with advance production: Experimental evidence. Journal of Economic Behavior & Organization

124. Selten R., 2001. What Is Bounded Rationality?. In: Bounded Rationality – The Adaptive Toolbox. USA. MIT

125. Shanteau J. & Pingenot A., 2009. Subjective Expected Utility Theory. In Encyclopedia of Medical Decision Making. M.W. Kattan. Los Angeles. Sage Publications

126. Siegel E., 2016. Predictive Analytics. New Jersey. John Wiley & Sons

127. Simon H.A., 1997. Administrative Behavior. New York: The Free Press

128. Simon H.A., 03-1965. Administrative Decision-making. Source: Public Administration Review, Vol. 25, No. 1, Twenty-Fifth Anniversary Issue. Pp. 31-37. Published by: Wiley on behalf of the American Society for Public Administration. URL: http://www.jstor.org/stable/974005. Accessed: 30.10.2017

129. Simon H.A., 01-1959: Theories of Decision-Making in Economics and Behavioral Science. In: The American Economics Review. Band 49, Nr. 3

130. Slovic P. & Fischhoff B. & Lichtenstein S., 2008. Facts versus fear: Understanding perceived risk. In: Judgment under uncertainty: Heuristics and biases. Cambridge, USA. Cambridge University Press

131. Sußner C. & Kuckartz U. 2005. Das Experteninterview in der Bildungsforschung. Phillips-Universität Marburg. Fachbereich Erziehungswissenschaften

132. Taylor F.W., 09-2004. The Principles of Scientific Management. Original published 1911. EBook #6435. Gutenberg Project. http://public-library.uk/pdfs/8/917.pdf Accessed: 07.04.2018

133. Tompson S. & Parthasarathy S., 06-2006. Moore's law: the future of Si microelectronics. Materials Today. Vol. 9, No. 620, Pp 20 – 25

134. Valadares de Oliveira M.P. et al. 2011. Supply Chain Process Collaboration and Internet Utilization: An International Perspective of Business to Business Relationships. Economic and Business Review. Vol. 13 No. 4. Pp. 203 - 226

135. Verboeket V. & Krikke H., 2019. Additive Manufacturing: A Game Changer in Supply Chain Design. Logistics, 3, 13. www.mdpi.com/journal /logistics. Pp. 1 - 27. Accessed: 08.08.2019

136. Wannenwetsch H., 2007. Integrierte Materialwirtschaft und Logistik. Neustadt: Springer Verlag

137. Weber M., 1922. Wirtschaft und Gesellschaft. Teil 3 Typen der Herrschaft, Kapitel 6 Bureaukratie. https://www.kullabs.com/classes/subjects/units/lessons/notes/note-detail/5329 Accessed: 18.04.2018

138. Wei K.Q. & Zheng L., Xiang Q. & Chen X., 10-2010. Applications of RFID in a SCOR-model: Driven Enterprise Production System. Industrial Engineering and Engineering Management (IE&EM), IEEE 17th International Conference. Oct. 2010. Pp. 501-505

139. Westerman G. & Bonnet D. & McAfee A., 2014. Leading Digital. Boston: Harvard Business School Publishing

140. Wilenius M., 03-2014. Leadership in the sixth wave—excursions into the new paradigm of the Kondratieff cycle 2010–2050. European Journal of Futures Research. P. 2. Springerlink.com. Accessed: 01.04.2018

141. Wolcott R., 01-2018. How Automation Will Change Work, Purpose, and Meaning. Harvard Business Review

142. Xiao R. & Cai Z. & Zhang X., 2009. An optimization approach to cycle quality network chain based on improved SCOR model. Progress in Natural Science, 2009. ScienceDirect. Pp. 881-890 Accessed: 17.10.2019

143. Yeung K., 2017. Hyper nudge: Big Data as a mode of regulation by design. Information, Communication & Society. Vol. 20. No. 1. Pp. 118 - 136. Accessed: 26.01.2017

144. Zelinski P., 02/2016. Where 4.0 Might Go. http://www.mmsonline.com/ Accessed 10.04.2016

145. Zhang X.Z. & Liu J. J. & Xu Z.W., 03-2015. Tencent and Facebook Data Validate Metcalfe's Law. Journal of Computer Science and Technology. Vol. 30, Issue 2. Pp. 246–251

146. Zott C. & Amit R., 2017. Business Model Innovation: How to Create Value in a Digital World. Business Model Innovation. Vol. 9, No. 1, GfK MIR. De Gruyter Open. Accessed: 22.06.2017

Internet Sources

147. Achievements of Gottfried Wilhelm Leibnitz. http://www.nlb-hannover.de/Leibniz/Leibnizarchiv/Leben_und_Werk/. Accessed: 14.02.2018

148. Automation: https://hbr.org/2018/01/how-automation-will-change-work-purpose-and-meaning?utm_content=buffer4958a&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer. Accessed: 26.01.2018

149. Atanasoff Berry Computer. 2011. JVA Initiative Committee and Iowa State University. Accessed: http://jva.cs.iastate.edu/operation.php. Accessed: 15.02.2018

150. Blume L.E. & Easley D., 06-2007. Rationality. https://www.ihs.ac.at/publications/eco/visit_profs/blume/rat02.pdf. Accessed: 17.01.2018

151. Clauß M., 09-2001. Generic Modeling using UML extensions for variability. Dresden University of Technology. http://www-st.inf.tu-dresden.de/mc3/varUML Accessed: 15.04.2018

152. Definition of efficiency. Gabler Businsess Dictionary. https://wirtschaftslexikon.gabler.de/definition/effizienz-35160 Accessed: 29.03.2021

153. Definition of predictive analytics. https://www.predictiveanalyticstoday.com/what-is-predictive-analytics/. Accessed: 14.02.2018

154. Definition of intelligent: https://www.merriam-webster.com/dictionary/intelligent. Accessed: 10.04.2018

155. Forbes: https://www.forbes.com/sites/gilpress/2015/12/27/a-very-short-history-of-digitization/6/#3ec551cc2e62. Accessed: 14.02.2018

156. Forbes: https://www.forbes.com.cdn.ampproject.org/c/s/www.forbes.com/sites/bernardmarr/2018/08/06/7-job-skills-of-the-future-that-ais-and-robots-cant-do-better-than-humans/amp/. Accessed: 01.10.2018

157. Gartner Group. 2018. Gartner Hype Cycle. https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp. Accessed: 01.04.2018

158. Gartner Group. https://www.gartner.com/newsroom/id/3784363. Accessed: 01.04.2018

159. Globalization: http://www.globalization101.org. Accessed: 22.01.2018

160. Hess T. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/lexikon/technologien-methoden/Informatik--Grundlagen/digitalisierung Accessed: 03.01.2018

161. Hoßfeld S., 2016. Der Einfluss der Digitalisierung auf Entscheidungen in Organisationen. Online Survey. https://docs.google.com/forms/d/e/1FAIpQLSeZ8sSKWUn6bKdKZ9-yp6mwadEpUbGx1t_FhZbUj0FzkBRDEg/viewform?c=0&w=1. Accessed: 06.06.2018

162. Mann C. The End of Moore's Law. http://mprc.pku.edu.cn/courses/organization/autumn2013/paper/Moore's%20Law/The%20End%20of%20Moore's%20Law.pdf. Accessed: 27.12.2018

163. McLeod S., 2012. Experimental Method. https://www.simplypsychology.org/experimental-method.html Accessed: 03.06.2018

164. Online shops Deutschland: https://www.ehi.org/de/top-100-umsatzstaerkste-onlineshops-in-deutschland/. Data are based on revenue figures of 2016. Accessed: 09.07.2018

165. S&P Capital IQ. Top 10 Companies with Highest Market Capitalization Worldwide. https://www.bcg.com/publications/2017/digital-transformation-transformation-data-driven-transformation.aspx Accessed: 02.10.2017

166. Statistics: https://www.statista.com/statistics/263264/top-companies-in-the-world-by-market-value/ Accessed: 28.12.2017

167. Statistics: https://statistics.laerd.com/spss-tutorials/kendalls-tau-b-using-spss-statistics.php Accessed: 17.06.2018

168. Statistics: http://www.statisticssolutions.com/kruskal-wallis-test/ Accessed: 28.06.2018

169. Statistics: https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php Accessed: 16.06.2018

170. Statistics:https://www.researchgate.net/publication/27706391_An_Introduction_to_Structural_Equation_Modeling Accessed: 18.06.2018

171. Survey: https://de.statista.com/statistik/daten/studie/182510/umfrage/frauenanteil-in-fuehrungspositionen-nach-unternehmensgroesse/ survey from 2016 in Germany. Accessed: 21.04.2018

172. Wakefield J., 2015. Intelligent Machines: The jobs robots will steal first. 14.09.2015. http://www.bbc.com/news/technology-33327659 Accessed: 28.02.2018

173. WEF: https://www.weforum.org/agenda/2016/09/farewell-oil-hello-tech-the-world-s-5-most-valuable-companies-in-2006-and-2016 Accessed: 28.12.2017

174. WEF: https://amp-weforum-org.cdn.ampproject.org/c/amp.weforum.org/agenda/2016/01/8-jobs-every-company-will-be-hiring-for-by-2020 Accessed: 01.10.2018

175. Wirtschtschaftslexikon: http://wirtschaftslexikon.gabler.de/Archiv/72569/automatisierung-v7.html Accessed: 01.03.2018

176. Wolcott R., 01-2018. How Automation Will Change Work, Purpose, and Meaning. Harvard Business Review. https://hbr.org/2018/01/how-automation-will-change-work-purpose-and-meaning?utm_content=buffer4958a&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer Accessed: 26.01.2018

APPENDIX

Appendix 1 Structured Professionals Interview: 'The Impact of Digitalization of Decision-Making'

1. **Interviewee**
   a. Name:
   b. Job title:
   c. Work experience in current position:
   d. Area of expertise:

2. **Organization**
   a. Industry:
   b. Size revenue/employees:

3. How do you evaluate the relevance of digitalization for organizations in general?
   Low - High
   1 / 2 / 3 / 4 / 5

4. Effects digitalization decision-making in organizations in general?
   Yes / No

5. How do you evaluate the relevance of digitalization in your organization?
   Low - High
   1 / 2 / 3 / 4 / 5

6. How do you evaluate the relevance of digitalization of decision-making or decision support in your organization?
   a. Status Quo (today)
      Low - High
      1 / 2 / 3 / 4 / 5

   b. Future State (tomorrow)
      Low - High
      1 / 2 / 3 / 4 / 5

7. Which relevance have the following influencing factors for digital decisions?

	Low - High
a. Emotional factors of decision-making	1 / 2 / 3 / 4 / 5
b. Increased complexity of decision-making	1 / 2 / 3 / 4 / 5
c. Increased reaction rate	1 / 2 / 3 / 4 / 5
d. New technologies	1 / 2 / 3 / 4 / 5
e. New organizational challenges	1 / 2 / 3 / 4 / 5
f. Further influencing factors?	

8. Which areas of digitalization are important? (intensity of characteristics)

		Low - High
a.	Big Data	1 / 2 / 3 / 4 / 5
b.	Automation	1 / 2 / 3 / 4 / 5
c.	Integration	1 / 2 / 3 / 4 / 5
d.	Customer Journey	1 / 2 / 3 / 4 / 5
e.	New business models	1 / 2 / 3 / 4 / 5
f.	Further areas of digitalization?	

_____

9. Which areas are already realized in your organization?

		Low - High	
a.	Big Data	1 / 2 / 3 / 4 / 5	_____
b.	Automation	1 / 2 / 3 / 4 / 5	_____
c.	Integration	1 / 2 / 3 / 4 / 5	_____
d.	Customer Journey	1 / 2 / 3 / 4 / 5	_____
e.	New business models	1 / 2 / 3 / 4 / 5	_____
f.	Further areas of realization?		

_____

Which areas of digitalization will be realized within the next 24 months in your organization?

		Low - High	
g.	Big Data	1 / 2 / 3 / 4 / 5	_____
h.	Automation	1 / 2 / 3 / 4 / 5	_____
i.	Integration	1 / 2 / 3 / 4 / 5	_____
j.	Customer Journey	1 / 2 / 3 / 4 / 5	_____
k.	New business models	1 / 2 / 3 / 4 / 5	_____
l.	Further areas of realization?		

_____

10. Do you think, that digitalization of decision-making will improve the result of this decision?
    Yes / No

11. Do you see further aspects of digitalization in your organization?
    a. _____
    _____
    b. _____
    _____

Appendix 2 Structure of Interview Partner

	Position	Since	Area of Expertise	Industry	Revenue (mio €)	Employees
1	CIO	2005	IT Management, Project Management	Textile	1600	8700
2	Professor	2004	Performance Evaluation and modeling adaptive systems	University	n.a.	n.a.
3	Managing Director	2012	Implementation and Optimization of Supply Chain	IT Consulting	4	40
4	CFO	2002	Logistics, HR, IT, Marketing, Controlling, Order Processing	Service	n.a.	50
5	Managing Director, Owner	2010	Management, Development and Strategy	IT Consulting	3	35
6	Business Unit Head	2015	Sales Management and Change Management	Chemistry	450	1100
7	Managing Director	2014	Sales and Procurement Development	Machinery	60	350
8	Finance Director	2008	Finance Process Optimization	Packaging	650	2700
9	Production Director	2016	Optimization in Production, Processed food, Packaging, Lean and General Management	Verpackung	600	1000
10	Controlling Manager	1998	Optimization of Processes and IT Implementation	Metal Processing	n.a.	500
11	Head of Strategy Office	2014	Strategy and Organizational Development, Process Optimization	Pharma	35000	28000
12	Managing Director & Owner	2008	Process Optimization, ITIL Knowledge, General Management	Consulting	2	12
13	General Manager	2008	Optimization, General Management, Business Process Reengineering	Packaging	5000	20000
14	Managing Director	1996	Sales, Controlling, General Management	Whole Sale & Export	160	1700
15	CEO	1999	General Management, Process Optimization	Electronics	220	2300
16	Director Group Accounting	2000	Financial Processes, Process Optimization, General Management	Automotive	720	8500
17	Senior Mgnt. Consultant	2016	Digital, E-Commerce, E-Business, Change Management, Marketing,	Consulting	11700	22000
18	Head of HR	2006	General Management, Strategy, Business Development	Paper & Packaging	2200	10000
19	CFO	2013	Commercial, Procurement, IT, M&A, Performance Management	Ink Supplier	2500	8000
20	Ass. Prof.		Business	Education		400
21	Managing Director	2012	Sales Process Optimization, General Management,	Processed Food	170	600

Appendix 3 Online Questionnaire ‘Supply Chain Decision‘

1. Interviewee
    a. Age:
    b. Gender:
    c. Job title:
2. Interviewee Organization
    a. Industry:
    b. Company size by revenue:
    c. Company size by employees:

3. Customer forecast data for the supply chain process (x1)
    a. How do you process from your customer forecast data for the supply chain workflow?

Manual	**More Manual**	**Balanced**	**More Digital**	**Digital**
1	2	3	4	5

    b. Is the processing of these customer forecast data for supply chain a completely automated decision or a decision support process?

Decision Support	**More Decision Support**	**Balanced**	**More Automated Decision**	**Automated Decision**
1	2	3	4	5

    c. Any comments on data delivery on customer forecast?

---

    d. How difficult was to answer the question “customer forecast data for supply chain“?

Easy	**Partly Easy**	**Undecided**	**Partly Difficult**	**Difficult**
1	2	3	4	5

4. Data transfer into the material management system (x2)

a. How do you transfer the customer data into your material management system?

Manual	More Manual	Balanced	More Digital	Digital
1	2	3	4	5

b. Is the processing in the material management system a completely automated decision or a decision support process?

Decision Support	More Decision Support	Balanced	More Automated Decision	Automated Decision
1	2	3	4	5

c. Any comments on data transferring into the material management system?

---

d. How difficult was to answer the question “data transfer into material management system“?

Easy	Partly Easy	Undecided	Partly Difficult	Difficult
1	2	3	4	5

5. Data transfer into the production planning system (x3)

a. How do you transfer the data into your production planning system?

Manual	More Manual	Balanced	More Digital	Digital
1	2	3	4	5

b. Is the processing in the production planning system a completely automated decision or a decision support process?

Decision Support	More Decision Support	Balanced	More Automated Decision	Automated Decision
1	2	3	4	5

c. Any comments on data transferring into the production planning system?

---

d. How difficult was to answer the question “data transfer into production planning system“?

Easy	Partly Easy	Undecided	Partly Difficult	Difficult
1	2	3	4	5

6. Data transfer into the inventory management system (x4)

a. How do you transfer the data into your inventory management system?

Manual	More Manual	Balanced	More Digital	Digital
1	2	3	4	5

b. Is the processing in the inventory management system a completely automated decision or a decision support process?

Decision Support	More Decision Support	Balanced	More Automated Decision	Automated Decision
1	2	3	4	5

c. Any comments on data transferring into the inventory management system?

---

d. How difficult was to answer the question “data transfer into production planning system“?

Easy	Partly Easy	Undecided	Partly Difficult	Difficult
1	2	3	4	5

7. Data transfer for customer order confirmation (x5)

a. How do you confirm the customer order?

Manual	More Manual	Balanced	More Digital	Digital
1	2	3	4	5

b. Is the process of customer order confirmation a completely automated decision or a decision support process?

Decision Support	More Decision Support	Balanced	More Automated Decision	Automated Decision
1	2	3	4	5

c. Any comments on customer order confirmation?

---

d. How difficult was to answer the question “customer order confirmation“?

Easy	Partly Easy	Undecided	Partly Difficult	Difficult
1	2	3	4	5

8. Overall evaluation of the entire process (x6)

a. How do you evaluate the digitalization of your entire supply chain process overall?

Manual	More Manual	Balanced	More Digital	Digital
1	2	3	4	5

b. Is the entire supply chain process a completely automated decision or a decision support process?

Decision Support	More Decision Support	Balanced	More Automated Decision	Automated Decision
1	2	3	4	5

c. Any comments on overall supply chain process?

---

d. How difficult was to answer the question “overall evaluation of the supply chain process“?

Easy	Partly Easy	Undecided	Partly Difficult	Difficult
1	2	3	4	5

9. Please evaluate your goal for automation of the supply chain process? (y_0)

a.	Reduction of costs		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
b.	Reduction of working capital		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
c.	Growth of revenue		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
d.	Others:		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5

10. Please evaluate the achievement of your goals in your supply chain process? (y_1)

a.	Reduction of costs		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
b.	Reduction of working capital		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
c.	Growth of revenue		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5
d.	Others:		**Fully Agree**	**Agree**	**Undecided**	**Disagree**	**Fully Disagree**
			1	2	3	4	5

11. Overall evaluation: have you reached by digitalization of your supply chain a more efficient decision process? (y_2)

Fully Agree	**Agree**	**Balanced**	**Disagree**	**Fully Disagree**
1	2	3	4	5

12. What do you think, to what extend digitalization of decision-making has a relevance for your industry?

Industry:_____

Extreme Low	**Low**	**Medium**	**High**	**Extreme High**
1	2	3	4	5

Appendix 4 Link & QR Code to Online Questionnaire

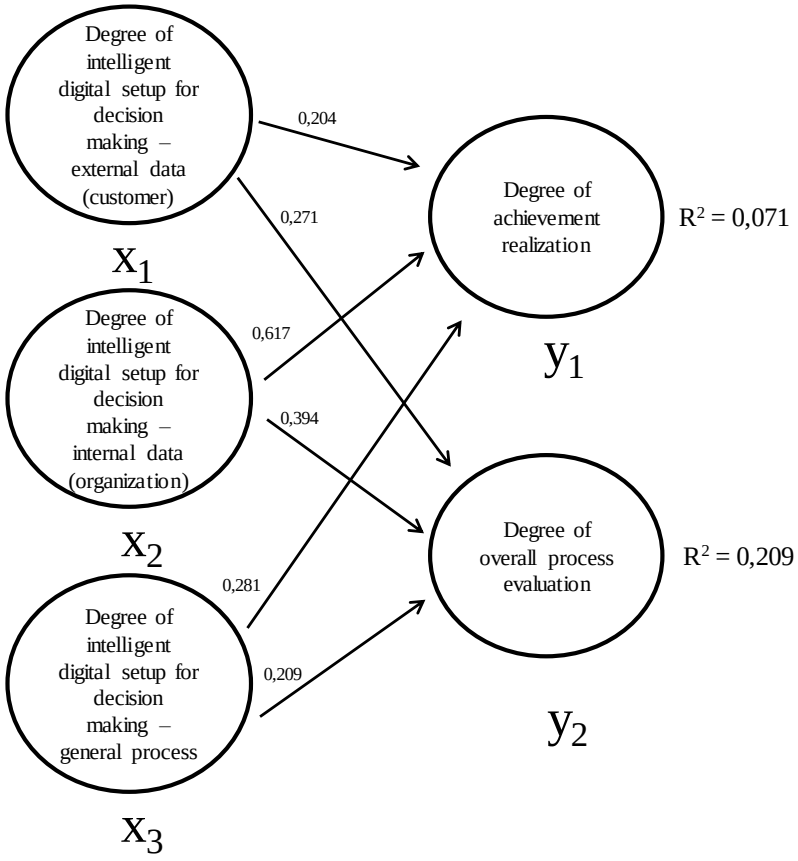
Following the link and the QR code for the online questionnaire, which is located at google forms. Using a QR code reader app, will enable access to the questionnaire. Due to the reference group, the questionnaire was executed in German.

https://docs.google.com/forms/d/e/1FAIpQLSeZ8sSKWUn6bKdKZ9-yp6mwadEpUbGx1t_FhZbUj0FzkBRDEg/viewform

Appendix 5 Complementary Statistical Analysis

Structural Equation Model with Statistical Significance and Coefficient of Determination

Structural Equation Model for Model Testing the Hypothesis
(Statistical Significane [p] and Coefficient of Determination [R^2])

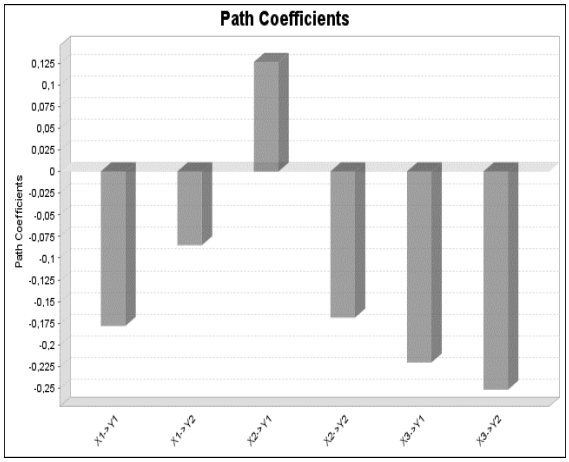


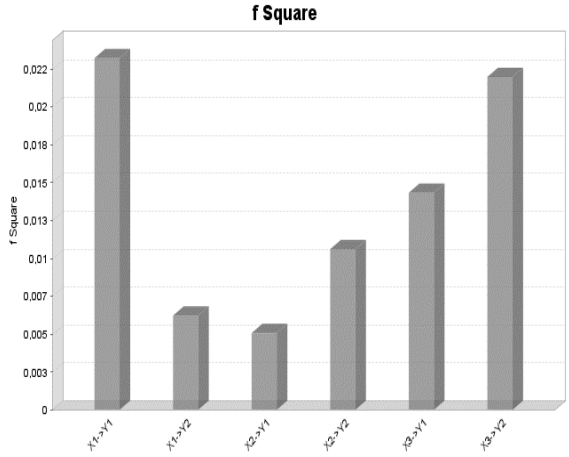
Discriminant Validity of Structural Equation Model

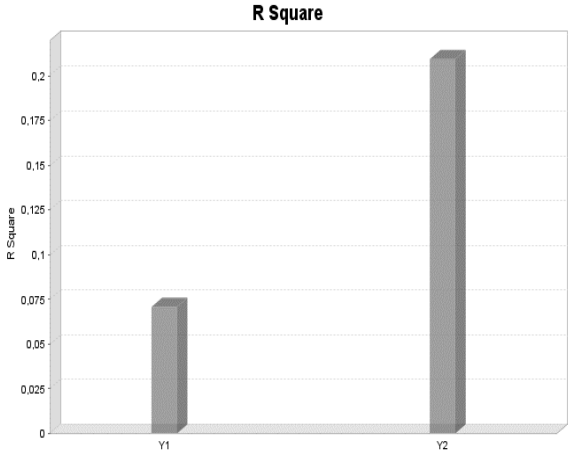
Fornell-Larcker Criterion

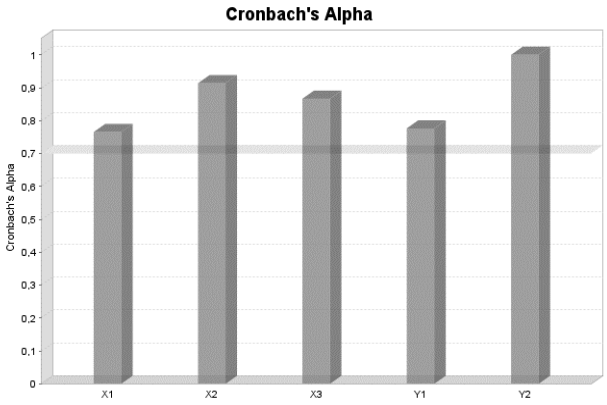
	x_1	x_2	x_3	y_1	y_2
x_1	0,900				
x_2	0,513	0,790			
x_3	0,562	0,838	0,939		
y_1	-0,237	-0,150	-0,215	0,832	
y_2	-0,313	-0,424	-0,441	0,571	1,000

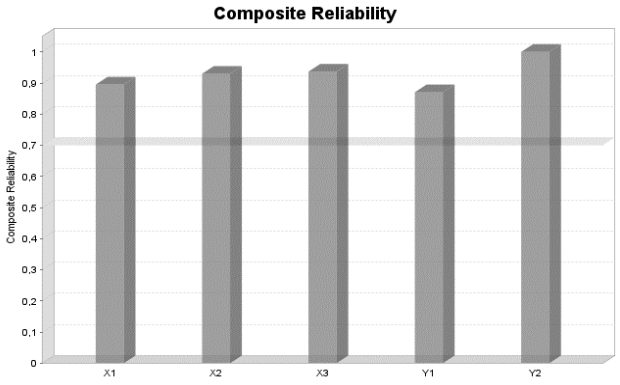
Graphical Analysis of Structural Equation Model (by Smart PLS)

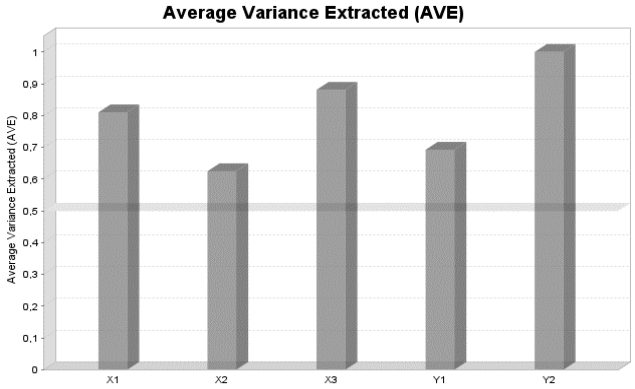







Cronbach's Alpha
Cronbach's Alpha
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
X1
X2
X3
Y1
Y2


Composite Reliability
Composite Reliability
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
X1
X2
X3
Y1
Y2


Average Variance Extracted (AVE)
Average Variance Extracted (AVE)
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
X1
X2
X3
Y1
Y2

„Coefficient of Correlation, Coefficient of Determination, Statistical Significance & Random Sample based on Spearman Rho"

(Author's construction)

		9.a. Goal of cost reduction	9.b. Goal of working capital reduction	9.c. Goal of revenue growth	10.a. Achievement of cost reduction	10.b. Achievement of working capital reduction	10.c. Achievement of revenue growth	11.a. Overall: have you reached by digitalization a more efficient process?
3.a. Customer forecast data processing - manual or digital	Correlation Coefficient	-0,088	-0,087	-0,109	-0,225	-0,208	-0,129	-0,274
	Coefficient of Determination	0,008	0,008	0,012	0,051	0,043	0,017	0,075
	Statistical Significance	0,376	0,387	0,272	0,025	0,039	0,202	0,006
	Random Sample	104	102	104	99	98	99	101
3.b. Customer forecast data processing - automated decision or decision support	Correlation Coefficient	0,031	-0,028	-0,134	-0,216	-0,123	-0,207	-0,291
	Coefficient of Determination	0,001	0,001	0,018	0,047	0,015	0,043	0,085
	Statistical Significance	0,755	0,78	0,175	0,032	0,229	0,04	0,003
	Random Sample	104	102	104	99	98	99	101
4.a. Data transfer into material management system - manual or digital	Correlation Coefficient	-0,053	0,07	0,019	-0,185	-0,135	-0,242	-0,421
	Coefficient of Determination	0,003	0,005	0,000	0,034	0,018	0,059	0,177
	Statistical Significance	0,596	0,493	0,853	0,069	0,188	0,017	0
	Random Sample	101	99	101	97	96	97	99
4.b. Data transfer into material management	Correlation Coefficient	-0,166	0,018	-0,077	-0,19	-0,024	-0,181	-0,315
	Coefficient of Determination	0,028	0,000	0,006	0,036	0,001	0,033	0,099

system - automated decision or decision support	Statistical Significance	0,093	0,861	0,438	0,06	0,817	0,073	0,001
	Random Sample	103	101	103	99	98	99	101
5.a. Data transfer into production planning system - manual or digital	Correlation Coefficient	-0,284	-0,065	-0,143	-0,186	-0,147	-0,196	-0,408
	Coefficient of Determination	0,081	0,004	0,020	0,035	0,022	0,038	0,166
	Statistical Significance	0,004	0,517	0,152	0,069	0,154	0,054	0
	Random Sample	102	101	102	97	96	97	99
5.b. Data transfer into production planning system - automated decision or decision support	Correlation Coefficient	-0,206	0,043	-0,142	-0,121	-0,043	-0,207	-0,336
	Coefficient of Determination	0,042	0,002	0,020	0,015	0,002	0,043	0,113
	Statistical Significance	0,039	0,672	0,156	0,236	0,678	0,042	0,001
	Random Sample	101	100	101	97	96	97	99
6.a. Data transfer into inventory management system - manual or digital	Correlation Coefficient	-0,096	-0,116	-0,094	-0,158	-0,159	-0,227	-0,364
	Coefficient of Determination	0,009	0,013	0,009	0,025	0,025	0,052	0,132
	Statistical Significance	0,332	0,245	0,347	0,12	0,119	0,025	0
	Random Sample	103	102	103	98	98	98	100
6.b. Data transfer into inventory management system - automated decision or decision support	Correlation Coefficient	-0,053	0,026	-0,097	-0,136	-0,093	-0,211	-0,282
	Coefficient of Determination	0,003	0,001	0,009	0,018	0,009	0,045	0,080
	Statistical Significance	0,593	0,792	0,327	0,18	0,36	0,037	0,004
	Random Sample	103	102	103	98	98	98	100

7.a. Data transfer for customer order confirmation -manual or digital	Correlation Coefficient	-0,09	0,108	-0,049	-0,119	0,039	-0,104	-0,414
	Coefficient of Determination	0,008	0,012	0,002	0,014	0,002	0,011	0,171
	Statistical Significance	0,364	0,279	0,622	0,24	0,702	0,307	0
	Random Sample	104	102	104	99	98	99	101
7.b. Data transfer for customer order confirmation - automated decision or decision support	Correlation Coefficient	-0,098	-0,06	0,074	-0,016	0,004	0,136	-0,259
	Coefficient of Determination	0,010	0,004	0,005	0,000	0,000	0,018	0,067
	Statistical Significance	0,324	0,55	0,458	0,875	0,97	0,18	0,009
	Random Sample	104	102	104	99	98	99	101
8.a. Overall evaluation of the process - digital or manual	Correlation Coefficient	-0,065	0,025	-0,083	-0,299	-0,157	-0,268	-0,509
	Coefficient of Determination	0,004	0,001	0,007	0,089	0,025	0,072	0,259
	Statistical Significance	0,513	0,802	0,402	0,003	0,123	0,007	0
	Random Sample	104	102	104	99	98	99	101
8.b. Overall evaluation of the process - automated decision or decision support	Correlation Coefficient	-0,07	0,054	-0,092	-0,202	-0,138	-0,213	-0,398
	Coefficient of Determination	0,005	0,003	0,008	0,041	0,019	0,045	0,158
	Statistical Significance	0,478	0,59	0,351	0,045	0,175	0,034	0
	Random Sample	104	102	104	99	98	99	101

„Coefficient of Correlation, Coefficient of Determination, Statistical Significance & Random Sample based on Kendell-Tau-b"

(Author's construction)

		9.a. Goal of cost reduction	9.b. Goal of working capital reduction	9.c. Goal of revenue growth	10.a. Achievement of cost reduction	10.b. Achievement of working capital reduction	10.c. Achievement of revenue growth	11.a. Overall: have you reached by digitalization a more efficient
3.a. Customer forecast data processing - manual or digital	Correlation Coefficient	-0,074	-0,073	-0,094	-0,199	-0,176	-0,109	-0,23
	Coefficient of Determination	0,005	0,005	0,009	0,040	0,031	0,012	0,053
	Statistical Significance	0,376	0,375	0,243	0,02	0,039	0,191	0,005
	Random Sample	104	102	104	99	98	99	101
3.b. Customer forecast data processing - automated decision or decision support	Correlation Coefficient	0,026	-0,023	-0,108	-0,193	-0,106	-0,175	-0,25
	Coefficient of Determination	0,001	0,001	0,012	0,037	0,011	0,031	0,063
	Statistical Significance	0,76	0,79	0,19	0,028	0,224	0,041	0,003
	Random Sample	104	102	104	99	98	99	101
4.a. Data transfer into material management system - manual or digital	Correlation Coefficient	-0,046	0,057	0,012	-0,165	-0,119	-0,203	-0,358
	Coefficient of Determination	0,002	0,003	0,000	0,027	0,014	0,041	0,128
	Statistical Significance	0,587	0,492	0,879	0,054	0,161	0,015	0
	Random Sample	101	99	101	97	96	97	99
4.b. Data transfer into material management system - automated decision or decision support	Correlation Coefficient	-0,141	0,014	-0,067	-0,166	-0,023	-0,157	-0,266
	Coefficient of Determination	0,020	0,000	0,004	0,028	0,001	0,025	0,071
	Statistical Significance	0,092	0,862	0,408	0,052	0,784	0,057	0,001
	Random Sample	103	101	103	99	98	99	101
5.a. Data transfer into production planning system - manual or digital	Correlation Coefficient	-0,246	-0,055	-0,117	-0,169	-0,132	-0,166	-0,351
	Coefficient of Determination	0,061	0,003	0,014	0,029	0,017	0,028	0,123
	Statistical Significance	0,003	0,506	0,145	0,048	0,121	0,046	0
	Random Sample	102	101	102	97	96	97	99

5.b. Data transfer into production planning system - automated decision or decision support	Correlation Coefficient	-0,177	0,037	-0,117	-0,107	-0,039	-0,177	-0,286
	Coefficient of Determination	0,031	0,001	0,014	0,011	0,002	0,031	0,082
	Statistical Significance	0,036	0,657	0,15	0,213	0,648	0,034	0,001
	Random Sample	101	100	101	97	96	97	99
6.a. Data transfer into inventory management system - manual or digital	Correlation Coefficient	-0,083	-0,095	-0,078	-0,139	-0,146	-0,191	-0,31
	Coefficient of Determination	0,007	0,009	0,006	0,019	0,021	0,036	0,096
	Statistical Significance	0,315	0,244	0,333	0,102	0,082	0,021	0
	Random Sample	103	102	103	98	98	98	100
6.b. Data transfer into inventory management system - automated decision or decision support	Correlation Coefficient	-0,045	0,021	-0,078	-0,118	-0,09	-0,177	-0,232
	Coefficient of Determination	0,002	0,000	0,006	0,014	0,008	0,031	0,054
	Statistical Significance	0,587	0,794	0,331	0,169	0,283	0,034	0,005
	Random Sample	103	102	103	98	98	98	100
7.a. Data transfer for customer order confirmation - manual or digital	Correlation Coefficient	-0,077	0,091	-0,037	-0,102	0,032	-0,085	-0,348
	Coefficient of Determination	0,006	0,008	0,001	0,010	0,001	0,007	0,121
	Statistical Significance	0,353	0,27	0,64	0,233	0,702	0,307	0
	Random Sample	104	102	104	99	98	99	101
7.b. Data transfer for customer order confirmation - automated decision or decision support	Correlation Coefficient	-0,084	-0,052	0,066	-0,013	0	0,107	-0,214
	Coefficient of Determination	0,007	0,003	0,004	0,000	0,000	0,011	0,046
	Statistical Significance	0,309	0,524	0,41	0,878	0,997	0,192	0,009
	Random Sample	104	102	104	99	98	99	101
8.a. Overall evaluation of the process - digital or manual	Correlation Coefficient	-0,058	0,022	-0,071	-0,274	-0,14	-0,228	-0,444
	Coefficient of Determination	0,003	0,000	0,005	0,075	0,020	0,052	0,197
	Statistical Significance	0,493	0,791	0,388	0,002	0,104	0,007	0
	Random Sample	104	102	104	99	98	99	101

8.b. Overall evaluation of the process - automated decision or decision support	Correlation Coefficient	-0,063	0,043	-0,081	-0,182	-0,123	-0,188	-0,343
	Coefficient of Determination	0,004	0,002	0,007	0,033	0,015	0,035	0,118
	Statistical Significance	0,461	0,609	0,323	0,037	0,155	0,027	0
	Random Sample	104	102	104	99	98	99	101