Augmented Decision Making in Purchasing and Supply Management (PSM): Overcoming Bounded Rationality

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ABSTRACT,
This thesis explores how digital technologies, including those associated with Industry 4.0, can enhance human expertise in proactive risk management within Procurement and Supply Management (PSM). Based on an extensive literature review and qualitative interviews with professionals from eight organisations, the study examines how tools like Artificial Intelligence (AI), Big Data Analytics (BDA), Enterprise Resource Planning (ERP) systems, and Digital Twins support human decision making. The findings show that effective augmentation goes beyond automating routine tasks. Digital technologies help overcome bounded rationality and improve risk identification and assessment. However, these tools are most effective when combined with human judgment. Thanks to this "digitalisation," PSM roles are shifting more from operational and transactional tasks to strategic and collaborative functions. This evolution requires professionals to develop new capabilities in digital literacy, data management, systems thinking, and analytical reasoning. While traditional skills like negotiation remain important, they are now applied in more data driven and relational ways. For managers, the study recommends investing not just in technologies but also in employees and data driven decision support. Building a model where technology enhances rather than replaces human input is key to effective proactive risk management. Limitations of the thesis include the study's small, purposive sample and qualitative approach, which may limit the generalisability of the findings. Future research should examine evolving risk management skills in an augmented PSM environment, the ethical dimensions of AI in PSM, as well as the impact of decentralised structures on proactive risk management.

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Digital Transformation, Digitalisation, Industry 4.0, Augmentation, Bounded Rationality, Risk Management.

1. INTRODUCTION

The use of Information Technology (IT) in Purchasing and Supply Management (PSM) has evolved significantly. From the automation of basic administrative activities and improving production planning in the 1960s and 1970s to e-procurement, e-sourcing and e-auctions in the 2000s (Rozemeijer, 2022, pp. 346, 350). In recent years, growing product and service sophistication, the rise of e-business, increased data availability, outsourcing and globalisation have contributed to a more complex supply chain environment (Christopher & Peck, 2004, p. 1; Gurtu & Johny, 2021, pp. 1-2; Harland et al., 2003, p. 52). This digital transformation has been further accelerated by the emergence of Industry 4.0 (I4.0), characterised by an integration of Cyber-Physical Systems (CPS) and the Internet of Things (IoT) (Bienhaus & Haddud, 2018, p. 965; Fähndrich, 2023, pp. 11-12; Knudsen, 2020, p. 2; Schallmo et al., 2018, p. 3). These technologies use automation, digitalisation and connectivity to enable real-time coordination and management of the value creation network (Jahan & Habib, 2025, p. 53; Kagermann, 2013, pp. 5, 22, 32; Weyer et al., 2015, p. 580). As I4.0 technologies take off, the concept of Procurement 4.0 has also gained attention (Jain et al., 2024, p. 10295). Procurement 4.0 refers to the application of I4.0 tools such as CPSs, IoT, Big Data Analysis (BDA) and Artificial Intelligence (AI) in the field of PSM (Althabatah et al., 2023, pp. 1-2, 5; Bueno et al., 2024, pp. 2-3). Technologies like BDA and AI can process large volumes of data and are not constrained by information overload or cognitive limitations and can therefore overcome the traditional form of bounded rationality (Edmunds & Morris, 2000, p. 18; Jones, 1999, p. 297; Leyer & Schneider, 2021, p. 712; Simon, 1990, p. 15).

Within this context, two complementary approaches are central to digital transformation: automation and augmentation (Chukwuani & Egiyi, 2020, p. 444; Colombo et al., 2023, p. 1; Weyer et al., 2015, p. 580). Automation enhances efficiency by streamlining repetitive, low-value tasks, whereas augmentation improves effectiveness by supporting complex decision making where human knowledge is used to complement available data and enhance responsiveness to risks (Colombo et al., 2023, pp. 1, 4-5; Weyer et al., 2015, p. 580). One area where this transformation is particularly impactful is risk management (Gurtu & Johny, 2021, pp. 1-2). Technologies such as those consistent with I4.0 can offer new opportunities for proactive risk management (Guo et al., 2025, p. 451; Harland et al., 2003, p. 54; Hartley & Sawaya, 2019, pp. 709-710; Kumar, 2022, p. 2; Mendes et al., 2022, pp. 1, 6, 10-11; Monczka; et al., 2022, p. 351; Peter, 2023, p. 42). However, while digital technologies offer powerful data processing capabilities, human strengths remain relevant. Humans excel in decision making, problem solving, being creative and flexible. They have strong qualities like personality, ingenuity and imagination, robots have yet to replicate (Isaza & Cepa, 2024, p. 2; Javaid et al., 2021, p. 71). Digital technologies, such as AI may be able to process unlimited amounts of data, but human feedback will continue to be needed even after Industry 4.0 gets wholly developed, stressing the need for effective augmentation (Javaid et al., 2021, p. 71; Leyer & Schneider, 2021, p. 712).

Despite the growing interest in Procurement 4.0, there is a lack of research on how augmentation addresses bounded rationality in proactive risk management. Existing studies often highlight the potential of technologies like AI and Robotic Process Automation (RPA) but rarely specify how they improve proactive risk strategies (Chukwuani & Egiyi, 2020, p. 444; Hartley & Sawaya, 2019, pp. 709-710). Additionally, research often neglects the human dimension and the evolving role of PSM professionals in the augmented proactive risk management context (Colombo et al., 2023, pp. 1, 5; Delke et al., 2023, pp. 1, 3, 13; Yoo et al., 2010, p. 8). To address these gaps, this thesis investigates the following research questions:

- *RQ1: How does augmentation in Purchasing and Supply Management (PSM) overcome bounded rationality conditions to improve proactive risk management strategies?*
- *RQ2: Which skills do PSM experts need to effectively leverage augmented technologies for proactive risk management?*

After this introduction, the thesis begins with a literature review to explore existing theories on digitalisation, augmentation, and risk management in PSM. A qualitative methodology follows, based on semi-structured interviews with professionals from eight companies with varying levels of digital maturity in different industries. The "Results" chapter documents the outcomes of the interviews. After this section, the discussion connects the results to theory and show that augmentation enables earlier signal detection, improved planning, and better data visualisation, essential to managing risk in unpredictable and complex environments. Decentralised structures were also found in the interviews to be of influence on both proactive risk management and bounded rationality. However, success depends on high-quality data, human oversight, and evolving professional skills, such as analytical as well as holistic supply chain thinking and data management (Bals et al., 2019, p. 6; Chukwuani & Egiyi, 2020, p. 445; Delke et al., 2023, p. 13; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5; Hallikas et al., 2020, p. 3; Vuchkovski et al., 2023, p. 10). Following this section, both the theoretical contributions and managerial implications will be presented. This paper will be concluded by reflecting on the limitations of the study and offering directions for future research.

2. LITERATURE REVIEW

2.1 Digital Transformation: the Evolution of PSM in an Industry 4.0 World

While there is no universally agreed-upon definition of digital transformation (Schallmo et al., 2018, p. 3), it is commonly understood as a profound organisational shift driven by digital technologies, innovative strategies, and new business models (Fähndrich, 2023, pp. 11-12; Knudsen, 2020, p. 2). This transformation involves fundamental changes in the social and technical structures of a company. Digital technologies are reshaping stakeholder roles, relationships, and practices across industries(Yoo et al., 2010, p. 8). In PSM, the digital journey began in the 1960s and 1970s with basic IT automation for repetitive tasks and production planning. The 1980s introduced

IT-supported decision-making and communication. By the 1990s, the internet enabled e-procurement, enhancing data exchange, increasing productivity and reducing workloads (Rozemeijer, 2022, pp. 346, 350). The 2000s expanded into e-sourcing and e-auctions; the 2010s brought cloud computing and e-SRM. The 2020s have seen the rise of AI, blockchain, and chatbots (Rozemeijer, 2022, p. 346). This ongoing evolution of PSM is closely linked to Industry 4.0 (I4.0) (Bienhaus & Haddud, 2018, p. 965), a concept introduced by the German government in 2011 (Jahan & Habib, 2025, p. 53). I4.0 represents the integration of digital and physical systems through Cyber Physical Systems (CPS) and the Internet of Things (IoT). These CPSs connect physical equipment or actions with software, allowing monitoring and control through networks. The Internet of Things (IoT) is a technology that connects everyday objects, or "things" to the internet. It allows devices to communicate with each other and be controlled remotely (Sharma & Sood, 2022, p. 35). The Internet of Things connects the entire manufacturing process, turning factories into smart environments (Kagermann, 2013, p. 14). Industry 4.0 uses automation, digitalisation and connectivity to help businesses connect at all levels. It does this by creating value networks that can be managed and coordinated in real-time, integrate processes across the entirety of the value chain and improve manufacturing system design. (Kagermann, 2013, pp. 5, 22, 32; Weyer et al., 2015, p. 580).

Procurement 4.0 further extends these technologies, such as CPS, IoT, Big Data Analytics, AI, Blockchain, and Digital Twins, into the procurement domain. While purchasing focuses on acquiring goods and services, procurement encompasses the entire process from identifying needs to managing supplier relationships (Althabatah et al., 2023, p. 5). It plays a strategic role in adding value and improving profitability. Procurement 4.0 strengthens collaboration and decision-making across the supply chain, enabling cost reduction, faster lead times, and increased efficiency (Bueno et al., 2024, pp. 2-3). These capabilities are also important for supporting sustainability and circular economy initiatives (Althabatah et al., 2023, pp. 1-2). Though rapidly evolving, its full implementation remains a work in progress (Jain et al., 2024, p. 10295).

2.2 Enabling Strategic PSM through Automation and Augmentation

Weyer et al. (2015, p. 580) mentions that there are three important paradigms or ideas upon which Industry 4.0 is based: smart products, smart machines and the augmented operator. Smart products store their own data and requirements, they are able to orchestrate and guide their own production, leading to self -organising and flexible manufacturing systems (Weyer et al., 2015, p. 580). Cyber Physical Production Systems (CPPS) can be considered as smart machines. They are able to communicate with other machines and manage production without a central control system. This results in a more flexible and adaptable manufacturing process (Weyer et al., 2015, p. 580). Lastly, Industry 4.0 considers human workers to be flexible but still essential to processes. Technology is used as support and products like smart glasses, tablets, and assistance systems can help human workers or "augmented operators" to manage complex tasks and intervene when needed (Weyer et al., 2015, p. 580).

Weyer et al. (2015, p. 580) loosely distinguishes two types of approaches to implement technologies in organisations. One where operations are taken over by technology and humans are not much involved, and one where humans use technology as support; automation and augmentation (Colombo et al., 2023, p. 1). This distinction raises a question: what motivates purchasing departments to invest in digitalisation and automate and augment their processes? A study by Colombo et al. (2023, pp. 4-5) reveals three drivers. The first driver, data aggregation, is about carefully selecting and harmonising data that contributes to improved decision making. Manual processes are prone to errors and an abundance of (irrelevant) data can result in data overload or "data smog" both impacting the quality of data (Edmunds & Morris, 2000, p. 18) . Digitalisation helps filter relevant data and enhance data quality (Colombo et al., 2023, pp. 4-5).

The second driver is efficiency. Automation helps to streamline processes, reduce overall costs, eliminate unnecessary approvals by skipping steps and quick decision making, and speed up data collection. These advantages may lead to faster results and better issue anticipation. Automation applies to tasks that are considered to not be complex, but rather simple and repetitive (Colombo et al., 2023, p. 5).

The third driver is effectiveness, which is supported by augmentation. This approach allows both humans and machines to work together to improve decision making, agility and supply chain resilience. Augmentation helps with complex and collaborative tasks, where human expertise is still necessary and indispensable to complement data (Colombo et al., 2023, p. 5). According to Delke et al. (2023, p. 3) Industry 4.0 technology can replace operational and low value tasks to allow experts in the field of PSM to focus more on strategic and value adding activities. Industry 4.0's Artificial Intelligence (AI), can assist or even has the potential to replace humans in decision making by processing large amounts of data quickly and rationally, allowing augmentation to overcome the so-called "bounded rationality" of humans (Leyer & Schneider, 2021, p. 712). Bounded rationality acknowledges the cognitive limitations of individuals, such as constraints on knowledge, emotions and computational capacity (Jones, 1999, p. 297; Simon, 1990, p. 15). Unlike humans, AI has the ability to process unlimited amounts of data and, while AI is not entirely free from bias as it may be trained with biased data, it does not suffer from the aforementioned human constraints, such as information overload or emotions (Edmunds & Morris, 2000, p. 18; Leyer & Schneider, 2021, p. 712).

Considering the evolving nature of PSM and Industry 4.0's shift toward enabling more strategic roles, this transformation broadens the scope of PSM and simultaneously exposes the field to a wider range of risks. This sets the stage for a deeper focus on risk management in PSM, where oversight and informed decisions are important for maintaining stability and value across the supply chain. (Althabatah et al., 2023, p. 3)

2.3 Risk Management in Digital Supply Chains

2.3.1 Risk Management and supply risk

Traditionally, PSM focused on cost reduction through strategies like global sourcing and supplier reduction. While effective for saving costs, these approaches increased distance between buyer and supplier and allowed for more dependency on fewer suppliers, raising the risk of disruptions and ethical concerns (Rozemeijer, 2022, pp. 53-54). Today, risk management plays a central role in procurement. Managers must balance cost, value, and risk while making strategic decisions and communicating clearly with leadership (Rozemeijer, 2022, pp. 53-54). The goal is to minimise negative impacts and support informed decision-making (Stoneburner et al., 2002, p. 4). According to Merna and Al-Thani (2008, pp. 2-3), effective risk management is a continuous process with three key aims: Regularly identify risks, analyse them based on the organisation's specific context, and respond with targeted, effective actions. In PSM, this is often referred to as "supply risk management", which focuses on reducing exposure to risks in supply markets and chains (Rozemeijer, 2022, p. 51). Although risks vary by industry or business area, some are common across supply chains. The weakest link determines the strength of a supply chain, so longer chains tend to carry higher risk (Gurtu & Johny, 2021, pp. 1-2). The concept of risk itself is subject to inconsistent and vague definitions (Carmichael, 2016, p. 186). For this context, the definition of risk from Zsidisin (2003, p. 217) will be adopted: Risk refers to the degree of uncertainty about the likelihood of significant or adverse outcomes resulting from a decision.

Risks in supply chains can originate from diverse sources and vary in nature (Aghajanian & Shevchenko-Perepy, 2018, pp. 732-734). This study focuses on supply risk, which is shaped by factors such as supplier availability, supplier switching costs, supply chain complexity, geographic location, inventory vulnerability, and the presence of substitutes (Rozemeijer, 2022, p. 107). Supply risk increases when critical products are sourced from a limited number of (global) suppliers without alternatives, and decreases when standardised goods are readily available from multiple sources (Rozemeijer, 2022, p. 107). Single sourcing heightens dependency and risk, whereas maintaining a diversified supplier base mitigates exposure, particularly when supplier reliability is uncertain (Hong & Lee, 2013, p. 68; Rozemeijer, 2022, p. 116). The globalisation of recent years has contributed to a more complex supply chain with an increase in supply risks (Christopher & Peck, 2004, p. 1).

Hallikas et al. (2004, p. 52) outline four key steps in a typical risk management process: identifying risks, assessing them, implementing appropriate management actions, and monitoring outcomes. Risk identification is the foundation of the process, where manual methods often suffer from delays, human error, and limited foresight. Technologies such as AI, Machine Learning, BDA, IoT, and cloud computing are transforming how risks are identified and managed (Kumar, 2022, p. 2; Peter, 2023, p. 42). These tools help collect and analyse large data volumes, identify trends, detect early warning signals, prevent human errors and support more accurate, data driven decisions (Mendes et al., 2022, p. 1; Peter, 2023, p. 42). AI helps model and predict outcomes based on how humans perceive the world, and is already being used in the aviation industry to mitigate human error and offer more predictive capabilities (Kumar, 2022, pp. 2-3; Mendes et al., 2022, p. 11).

To assess and manage supply risk, companies may use a tool like the Kraljic matrix, which categorises products into leverage, strategic, routine, and bottleneck items based on financial impact and supply risk (Rozemeijer, 2022, pp. 109-110). A similar tool uses the same four categories to analyse power dynamics between buyers and suppliers (Rozemeijer, 2022, p. 109). Additionally, the ABC analysis helps prioritise inventory by classifying products into A (very important), B (important), and C (least important) categories, ensuring time and resources are focused on the most critical items (Chu et al., 2008, p. 841).

2.3.2 Proactive and Reactive Risk Management

Understanding the types of products and suppliers a company relies on, the associated supply risks, and the appropriate sourcing strategies to mitigate those risks represents a proactive approach to risk management (Mendes et al., 2022, p. 6; Monczka; et al., 2022, p. 351). Predictive methods such as forecasting help identify latent risks and prevent disruptions or accidents (Harland et al., 2003, p. 54; Mendes et al., 2022, p. 10). For instance, bottleneck products which are low in financial impact but high in supply risk, require contingency planning, such as holding extra inventory or safety stock, arranging backup logistics, or sourcing alternatives (Rozemeijer, 2022, pp. 109-110). The process of supplier selection and assessment are also critical proactive measures. Conducting due diligence through requests for information, proposals, or quotations (RFI, RFP, RFQ) helps organisations choose reliable suppliers and manage risk effectively (Rozemeijer, 2022, p. 37). On the other hand, reactive risk management is essential when unexpected events arise (Monczka; et al., 2022, p. 351). Since not all risks can be predicted, managers must adapt, revise plans, and respond as needed (Pavlak, 2005, p. 36). However, cases like the 2008 financial crisis and COVID-19 show that early warning signs often go unheeded, suggesting that many "unexpected" risks could have been proactively addressed (Kumar, 2022, p. 1). In this way, recognising early signals is itself a proactive step. Moreover, reactive analysis after an incident occurs can help identify patterns and prevent recurrence (Mendes et al., 2022, p. 6).

With supply chain disruptions becoming more frequent and severe, reactive, short-term solutions are no longer sufficient. Companies must build robust response capabilities and efficient recovery mechanisms to stay resilient (Kähkönen & Patrucco, 2022, p. 2). Digital technologies support both proactive and reactive approaches by enabling data-driven insights, automation, and early warning systems. Collaboration through shared information, joint decision-making, resource alignment, and co-created knowledge play an important role for strengthening supply chain resilience (Guo et al., 2025, p. 451).

2.3.3 Digitalisation in Risk Management

Hartley and Sawaya (2019, pp. 709-710) explore how machine learning (ML), a subset of AI, is applied in PSM. ML uses algorithms to analyse data, identify patterns, and improve models over time without explicit programming, relying on consistent input data in the process. With the rise of data from Industry 4.0 technologies like IoT sensors, organisations now have more opportunities to enhance decision making in PSM. Key ML applications in PSM include demand forecasting and inventory optimisation, where sensors enable real-time demand detection in smart warehouses, creating Cyber-Physical Systems that communicate directly with suppliers, also building on the idea of supplier collaboration (Delke et al., 2023, p. 3; Guo et al., 2025, p. 451). Other uses involve warehouse scheduling, predictive maintenance, and, for this study relevant, risk assessment to identify potential disruptions and mitigate supply chain vulnerabilities (risk management) (Hartley & Sawaya, 2019, p. 710). In addition, Robotic Process Automation (RPA) is reshaping PSM by automating rule-based tasks such as data entry, form filling, and ERP data extraction (Chukwuani & Egiyi, 2020, p. 444; Delke et al., 2023, p. 3; Hartley & Sawaya, 2019, p. 709). RPA handles structured data (e.g. spreadsheets) but minimal amounts of unstructured data (e.g. emails, social media) because it ultimately relies on high quality data (Chukwuani & Egiyi, 2020, p. 445; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5). RPA boosts efficiency, reduces errors, cuts costs, and increases employee satisfaction (Flechsig et al., 2022, p. 5; Hartley & Sawaya, 2019, p. 709). In PSM, it is especially useful for automating repetitive tasks in sourcing, operations, and logistics, allowing staff to focus on strategic activities (Delke et al., 2023, p. 3).

Despite the growing role of digital tools, the literature has yet to explore in depth how augmentation or machine-human collaboration might help overcome bounded rationality in proactive risk management. This represents a significant research gap that the research in this thesis sets out to examine.

2.4 Human Roles and Skill Shifts in a Digitally Augmented PSM Function

Colombo et al. (2023, p. 1) argue that digital innovations may create anxiety over job security due to shifting competency requirements. As robots and automation tools grow more advanced, they increasingly handle operational tasks. However, PSM roles still involve complex, non-routine tasks that require human character traits such as judgment, creativity, and adaptability, which are not easily automated (Isaza & Cepa, 2024, p. 2; Javaid et al., 2021, p. 71). Consequently, rather than fully replacing human labour, digital transformation is expected to reshape tasks and require new capabilities from professionals that are more strategic in nature (Delke et al., 2023, p. 1; Isaza & Cepa, 2024, p. 2; Yoo et al., 2010, p. 8). For instance, being able to work with and manage data will become more important for PSM professionals in an Industry 4.0 context (Delke et al., 2023, p. 13; Vuchkovski et al., 2023, p. 10). New roles such as the “Master Data Manager” or “Data analyst” are just two examples of future roles needed within PSM (Delke et al., 2023, p. 13). Furthermore, analytical skills, Big Data Analytics and computer literacy are also identified by Bals et al. (2019, p. 6) to be essential PSM skills for the future. Furthermore, technological advancements as well as globalisation result in an increase in complex interconnected systems (Christopher & Peck, 2004, p. 1; Gurtu & Johny, 2021, pp. 1-2; Harland et al., 2003, p. 52).. Certain actions can echo across the globe as well as supply chains. Understanding what these complex systems exactly entail and examining more links in the supply chain as part of the PSM role require a skill called “systems thinking” (Bals et al., 2019, p. 6; Hallikas et al., 2020, p. 3).

These are broad assumptions about the future of PSM and related fields. However, the specific evolution of the PSM expert’s role in relation to proactive risk management remains underexplored in current research, forming a second gap that this thesis aims to address.

3. METHODOLOGY

3.1 Research design:

This thesis employs a qualitative and exploratory research design (Patton, 2002, p. 4). Given the shortage of academic literature on this emerging topic and the still evolving nature of automation, augmentation, and necessary skills in PSM risk management, context specific insights are needed and require careful interpretation. Rather than testing a theory, this study explores real world PSM practices and examines how digital technologies interact or collaborate with humans and their expertise. Research moves from specific observations to broader generalisations and is therefore inductive (Saunders et al., 2023, p. 157). This “inductive” thesis includes the earlier literature review of secondary data, examining existing literary evidence for augmentation and essential skills in PSM. Insights from this review inform the design of the primary research, which involves collecting data through semi-structured interviews with PSM professionals from various companies (Guerin et al., 2018, p. 63). The final stage involves a coding based analysis capturing dimensions like bounded rationality, the impact of augmentation on proactive risk management, the evolving role of PSM professionals and potential skill gaps.

3.2 Sampling process: Purposive Selection of PSM Experts

Nine PSM professionals from eight different companies were interviewed in Dutch, primarily in person, with two interviews conducted online, to serve as representatives of the wider professional population (Rai & Thapa, 2015, p. 2). Because the sampling method used is non-random, non-probabilistic and based on specific criteria, it is referred to as “purposive sampling” (Rai & Thapa, 2015, p. 5). Purposive sampling involves the choosing of participants who have certain characteristics that are important for the study. This is different from random sampling, which tries to include people from many different backgrounds to reduce bias and better represent the entire research population (Bullard, 2019, p. 1). In this study, PSM professionals are deliberately chosen as participants for the research based on their knowledge and expertise (Etikan et al., 2016, p. 2). Etikan et al. (2016, p. 3) proposes several purposive sampling methods, two of which are of influence on this research. Firstly, homogeneous sampling focuses on participants who share similar characteristics, such as age, culture, or, most relevant to this research, their employment role (Etikan et al., 2016, p. 3). The second purposive sampling method is called "expert sampling". This method calls for professionals in a specific field, in this case the field of PSM. It is considered to be especially useful in exploring new research areas as it draws on the insights of people with relevant knowledge and expertise (Etikan et al., 2016, p. 3).

Companies and PSM experts were contacted by phone and email, and ultimately chosen based on convenience and the company's level of digital maturity, whether they were early adopters or already experts in digital integration of PSM practices (Etikan et al., 2016, pp. 1-2). This variation allowed the research to capture a broader range of experiences and perspectives. The table below provides additional information with regard to the interview sample.

Inter-view	Duration	Industry	Function
IV1	00:51:47	Industrial Machinery and Automation	Supply Chain & Purchase Manager
IV2	00:41:55	Industrial Machinery and Automation	Purchaser
IV3	00:27:28	Industrial Machinery and Manufacturing	Production Manager
IV4	00:55:30	Technology	Purchaser
IV5	00:51:02	Industrial Equipment and Components	Project Purchaser
IV6	00:42:40	Chemical Distribution	Lead Buyer
IV7	00:24:34	Industrial Machinery and Automation	Two purchasers
IV8	00:44:53	Agribusiness	Supply Chain Manager

Table 1 – Interview Sample

3.3 Interviews and Data Collection: Capturing Expert Insights

The eight interviews in this study follow a semi-structured format supported by an interview guide (see Appendix A, p. 15-17) (Patton, 2002, pp. 343-344). Each interview includes a set of base questions which was consistent across all participants to make sure results can be compared in later stages. In addition, follow-up or probing questions may be used to explore specific answers in greater depth, depending on the quality and amount of detail of initial answers by interviewees (Patton, 2002, pp. 372-373). However, before asking any questions, informed consent was gathered (Patton, 2002, p. 407). With this consent, the interviewee was asked to agree to the recording of the interview and was informed about how the data would be processed and used (See Appendix B and C, p. 16-17 for the two consent forms). After this had been acknowledged on paper and/or on tape, five interview questions were asked focusing on five main areas derived from the literature review and multiple academic sources: (1) the company's proactive and reactive risk management practices, (2) challenges in risk identification and response, (3) the role of digitalisation in risk management, (4) technological opportunities for optimising risk processes, and (5) the competencies required to use digital tools effectively in risk management.

3.4 Data analysis: A Thematic Analysis Approach

After the interviews concluded, recordings were securely saved and then transcribed. Subsequently, theoretical patterns or "themes" present in the collected interview data were identified, analysed and interpreted using a Thematic Analysis (TA) approach. This method allows for an understanding of experiences, perceptions, and insights of PSM professionals regarding the related concepts (Clarke & Braun, 2017, p. 297). According to Terry et al. (2017, p. 21), TA can be used in most theoretical framework thanks to its flexibility and accessibility. First, a collective codebook was created with a colleague with whom the interviews were conducted. Then, data was individually coded using the codes from the codebook and qualitative data analysis software "ATLAS.ti". The coding process consisted of segmenting and labelling small parts of the data into meaningful units. These units, or codes, were then grouped into themes; bigger ideas with a shared meaning, that align with the research questions and theoretical concepts such as bounded rationality and proactive risk management strategies among others (Clarke & Braun, 2017, p. 297). After this step, the codes were compared, discussed, and altered if necessary, with a fellow student doing similar research and with whom interviews were conducted. This so-called "Intercoder Reliability" ensures a certain degree of consistency and objectivity of the data analysis by verifying that two researchers interpreted and coded data in the same way (O'Connor & Joffe, 2020, pp. 2-3). The Intercoder Reliability analysis yielded a Krippendorff's Alpha of 0.864 indicating a high degree of agreement between my colleague and me. As values above 0.80 are generally considered reliable, this suggests that the coding process was consistent and the results can be regarded as robust and trustworthy (Neuendorf, 2002, p. 143). For a full visualisation of the research presented in the thesis, please refer to Appendix D, p. 18.

4. RESULTS

To support the findings presented in this chapter, a cross-comparison table of the interviews is provided in Appendix E, p. 19-22. The table includes additional explanations and illustrative quotes linked to specific codes.

4.1 The effect of Augmentation on Proactive Risk Management

4.1.1 Navigating Unpredictability and Data Complexity

Interviewees emphasised the high level of unpredictability within today's globalised and interconnected supply networks. External shocks such as COVID-19, natural disasters, rapid upscaling, and geopolitical instability were frequently cited as major risk factors (IV1, IV2, IV4, IV5, IV6, IV7, IV8). One respondent noted the volatility of political leadership, stating: *"You never know if the Trump of today will remember the Trump of yesterday" (IV6).* Another respondent commented on the unpredictability of geopolitical conflicts: *"The war in Ukraine, for example. You can have all the technology in the world, but I do not believe anyone could have predicted exactly how this conflict would unfold" (IV5).* Additionally, several interviewees noted challenges in making timely decisions due to the volume, fragmentation, and complexity of available data (IV1, IV2, IV4, IV5, IV6, IV7, IV8). Interviewees highlighted the difficulty in identifying and structuring relevant data. As one participant explained, *"It is quite an art to register the right data from the enormous amount of data available. But you can register a lot. The question is whether it is always useful and usable" (IV5).* Another interviewee added, *"The data is available and you can manage on it, but it just takes a lot of time" (IV6).* This complexity is compounded by constantly changing variables, such as shifting product dependencies, supplier disruptions, and geopolitical developments (IV1, IV2, IV4, IV5, IV6, IV7, IV8). *"There is not really a funnel for purchasing or supply chain to make a decision. He [a purchaser] has to get many sources to really bring those data points to a workable risk analysis" (IV2).* IV8 also describes the standardisation of information and keeping it simple as one of the biggest challenges.

Furthermore, data maintenance was noted as a significant issue (IV1, IV2, IV4, IV5, IV6, IV7, IV8). Keeping dashboards updated and ensuring standardisation, uniformity and quality in data entries largely remains a manual process: *"Data has to be updated in the dashboard. This is mostly done manually," (IV5)* one respondent stated. Another added, *"Sometimes this can be automated, but other times I have to adjust tens of thousands of article numbers by hand"* (IV1). Inconsistent data entries were reported to cause further issues, as mismatches could compromise the reliability of tools such as Power BI. *"The quality of your data really is the fundament for these kind of [digital] activities" (IV8).*

4.1.2 Digital Applications and Identified Benefits for PSM

In response to these challenges, several participants pointed to the increasing importance of digital tools, such as Industry 4.0's Artificial Intelligence (AI), Big Data Analysis (BDA), Digital Twins, Electronic Data Interchange (EDI)/Application Programming Interface (API), Enterprise Resource Planning (ERP) systems and sensors to navigate the unpredictable and complex data environment.

First and foremost, the use of AI varied considerably among interviewees. Some reported only minimal use, such as employing tools like ChatGPT to generate reports or compare supplier offers (IV2, IV3). In contrast, others described more advanced applications, including AI tools used to analyse price data, identify trends, forecast and uncover interdependencies between products (IV1, IV4, IV5, IV6). Some respondents indicated using traditional supplier/product ABC and Kraljic analyses in combination with AI (IV1, IV5, IV6). One organisation also reported using AI for spend categorisation (IV6). Overall, respondents expressed optimism about the potential of AI in procurement and supply management. One participant noted, *"If they can bring this together with AI or something like that, it could already make a good decision for you. Maybe even better than when I see all those little data points and try to make sense of them. I think that's where the future is heading" (IV2).* The objectivity of AI was also highlighted: *"AI doesn't have those biases. It just sees ones and zeros, no emotions in between" (IV3).*

Moreover, IV1 described BDA to have a clear benefit *"You can analyse complex data more quickly and ultimately extract valuable information from a whole lot of data faster".* Other respondents shared this opinion and mostly use the technology to visualise, plan, analyse and see trends in data through, for example, dashboards on Power BI (IV1, IV3, IV4, IV5, IV6, IV8). The data for this BDA usually flows from the companies' ERP systems which is considered to be the backbone of a company's digitalisation infrastructure (IV1, IV2, IV3, IV4, IV5, IV6, IV7, IV8). *"ERP systems are enormous at every company" (IV1),* and *"the ERP system is the heart of the company. Risks are saved in this system and are also more visible that way" (IV3).* ERP systems allow for a centralised data overview where production can be inspected (IV3), information about orders can be registered (IV3), orders can be placed and forecasted (IV4).

Another Industry 4.0 technology, the Digital Twin, is used to simulate disruptions. (IV4 & IV8). *"For our most important product, a Digital Twin has been designed in which not a single component is the same as in the original and with a completely different supply chain channel. This is to prevent the risk of not being able to deliver it" (IV4).* IV8 also indicated that a prerequisite for a Digital Twin is high quality and standardised data.

Additionally, EDI and API are widely used by several interviewed companies to enhance communication and automate data exchange between themselves and their suppliers. These systems facilitate improved supplier collaboration by enabling data sharing. One participant explained: *"Then the system sends everything from one PO [Purchase Order] to suppliers and there is even the possibility to 100% auto PO. Then you do not need an operational buyer to place purchase orders" (IV1).* Another interviewee highlighted: *"I think that integrated systems such as EDI, API and Product Lifecycle Management systems all ensure data stays fresh and relevant and that there is less human action necessary" (IV4).* Both statements emphasise the advantage of reducing manual intervention through system integration.

Finally, several companies reported increasing use of sensors and digital monitoring to improve safety, efficiency, and service quality (IV1, IV2, IV3, IV8). Sensors serve as safeguards in production by checking components before they enter machines, reducing failure risk and enhancing reliability (IV1). Companies also analyse machine data to understand usage patterns (IV1, IV2) and performance (IV3). Real-time shopfloor monitoring tracks cycle times, errors, and production flow. Specialised sensors, like AIS sensors on ships, provide location and voyage data and are a way to map/trace products: "*That is a sensor that indicates where in the world a ship is located and also displays other information about the voyage" (IV2).* Some firms are also exploring service contracts that use sensor data to trigger automatic stock replenishment, enabling proactive inventory management (IV2).

4.1.3 Decentralised Structures for Data and Purchasing in Risk Management

Several large organisations in the study adopt decentralised structures in both data handling and purchasing. Instead of centralising responsibilities across all business units, tasks such as data entry and risk management are distributed locally (IV1, IV4, IV6, IV8). *"Every business unit has its own decentralised purchasing department" (IV4).* Each unit gathers data and maintains its own tailored dashboard for example, *"Each department has its own Power BI dashboard, with the specific fields they are responsible for completing" (IV1).* Central purchasing and software teams oversee standardisation across the organisation, ensuring consistency and relevance across departments (IV1, IV4).

4.1.4 Proactive Risk Management Strategies in Practise: Varying degrees of digitalisation

Interview findings revealed that contracting, fool-proof processes, local sourcing, networking, different types of component quality control, risk analysis/assessment, safety stock, supplier assessment and collaboration to be the main proactive risk management strategies.

The first way in which certain interviewee companies revealed to manage supply risks proactively is by formalising agreements through contracts and Service Level Agreements (SLAs) (IV1, IV2, IV3, IV4, IV8). As one respondent explained: *"You can see we increasingly try to capture things in SLAs and cooperation agreements to make sure liability and risks related to components can be passed on appropriately, from assembly all the way through to the sales side. For example, when it comes to warranty periods" (IV1).* SLAs not only help define mutual expectations but also clarify legal responsibility in case of damage or defects. Beyond legal agreements, trust and collaboration with suppliers remain essential. One interviewee noted: *"You have to trust each other and make good agreements, price agreements too" (IV3).* Firms also rely on contractual mechanisms to protect intellectual property and sensitive data: *"We try to enforce the proactive side through signed contracts and NDAs. The data we share with suppliers is confidential, and the products we hand over to them cannot be sold to anyone else" (IV4).* To complement contractual protections, one of the interviewees revealed the company also insures itself against logistical disruptions (IV4).

Some interviewees indicated that they proactively take steps to make processes fool-proof in order to reduce disruptions and lower the learning curve for new personnel. For example, IV6 and IV8 use a digital system to document and standardise procedures. Another participant explained, *"we increasingly solve that risk by simply making it fool-proof. Essentially taking as many measures as possible so that the operator or whoever is working with the machine basically cannot make a mistake" (IV2).* Another proactive risk management strategy involves having suppliers near production sites, which facilitates the quick return or replacement of faulty components, according to IV1, IV2, and IV7. *"We have about 80% of suppliers within an hour around our plant, so someone can quickly go there with a trailer or van and solve the problem" (IV1).*

Networking or *"extending more tentacles into the market" (IV2)* was another strategy for early risk detection. Respondents highlighted that strong connections with specialists and account managers provide timely alerts about potential issues (IV1, IV2). One said, *"If you have good contacts in certain branches, you are often the first to know because they see developments daily [...] it allows you to handle quicker than others" (IV1).* Account managers were similarly regarded as sensing mechanisms: "*They inform us early when something seems to be happening" (IV2).* This network expands the company's market reach, allowing faster responses to risks. As another participant stated, *"You can only do so much yourself." (IV2).* Interviewees described these networks as essential for maintaining awareness of risks beyond what digital systems alone can provide.

Several respondents also described quality control as a shared responsibility between the company and its suppliers (IV1, IV2, IV3, IV4). While incoming goods are not always inspected in full, many firms rely on suppliers' own outgoing controls and escalate quality checks when risks are higher. As one explained, *"We trust suppliers to ensure the quality of components, we only check quantities" (IV2).* One interviewee stated that functional and end-of-line tests are typically carried out at the supplier's site using the interviewee's company-owned test equipment, with data shared back to enable trend monitoring (IV4). To catch problems earlier, some companies build prototype machines internally to test new components over several months. This allows issues to surface before full production. However, reliance on late-stage detection by technicians can still occur: *"Often it's only noticed during production, when a technician flags a mismatch"* (IV1).

Furthermore, the interviewed companies indicated that they increasingly applying structured approaches to manage component-level risk. Respondents described the use of ABC analyses, the Kraljic matrix, FMEA scoring, and heatmaps to identify vulnerable parts and suppliers as well as for forecasting purposes (IV1, IV2, IV4, IV5, IV6, IV8). Even combining these traditional methods with ERP systems. *"Of course, there are also other mechanisms like the Kraljic matrix and similar tools, which you can use to categorise products or determine which quadrant a product falls into" (IV5).* Depending on the criticality of components, some "exotic" components are often listed with pre-defined alternatives in the bill of materials, and dual or multiple sourcing is common for high-risk items (IV4, IV6). *"We use different sourcing strategies for different categories of items. For each item category, we decide whether to purchase from one supplier, two, or multiple suppliers. For example, we currently purchase our most critical product from three suppliers, because we absolutely cannot afford to be unable to deliver it at any point" (IV4).* Moreover, risk incidents often trigger process changes. As one participant noted, *"We are frequently forced back to the drawing board when something goes wrong, to rethink suppliers or product groups" (IV2).*

Respondents also emphasised the importance of maintaining sufficient safety stock (IV1, IV2, IV4, IV6, IV8), especially after the disruptions experienced during the COVID-19 pandemic in 2021, which challenged just-in-time approaches (IV2). Safety stock levels are determined using supply chain data, including current lead times and product-specific information, often supported by digital systems to handle the complexity. This allows organisations to set optimal safety stocks and reorder quantities to ensure continuity, even if suppliers face issues. Some also keep local stock or equip technicians with necessary parts to enable quick sourcing on-site or regionally. *"The size of the safety stock can be determined based on the data points the supply chain provides. You really need to continuously measure the lead times of all your products, especially critical ones. Doing this manually takes a lot of effort. The only way to manage it effectively is by using systems to help" (IV1).*

Interviewees stated that supplier assessment is another proactive risk management strategy. Suppliers are inspected based on their ISO certification, audit performance, credit checks, quality, information safety, their supply chain management and price benchmarking (IV3, IV4, IV5, IV8). Information can be put in the ERP system or integrated into an approved supplier list that also needs regular updates (IV4, IV5). In addition, the results show that collaboration with suppliers often involves clear and active communication (IV7, IV4, IV8) and joint development efforts, particularly during prototype phases (IV1). Several companies highlighted the importance of aligning supplier innovation with their own product roadmaps and aiming for long term partnerships (IV1, IV8). One interviewee noted: *"We look at where suppliers' development is going within the next 10 years and how that fits with new machine developments, so joint development can be done" (IV1).* Trust was also mentioned and plays a critical role in supplier relationships (IV2, IV3, IV7). Some companies rely on suppliers to perform thorough exit quality controls and *"trust that suppliers safeguard the quality of components,"(IV2)* while their own inspections primarily focus on quantity verification (IV2). This differs per company and per product the company is processing. Additionally, long-term strategic partnerships were commonly emphasised, with some companies maintaining electronic data interchange (EDI) connections that enable direct system integration with suppliers (IV1, IV4, IV7). Proximity to suppliers also emerged as a factor in agility and responsiveness. One participant explained having *"a short line with a supplier in [location] if components are delayed or missing, they can quickly call to check availability and arrange immediate pickup" (IV7).*

4.2 Necessary Skillset for Augmented Proactive Risk Management

The majority of interviewees indicated that analytical thinking is becoming increasingly important for PSM professionals (IV1, IV2, IV4, IV5, IV6, IV8). The ability to perform analyses, interpret dashboards, and work with statistical data is now seen as essential. As one respondent stated: *"You do have to be able to see something when you look at data. You also need to be able to recognise where improvements can be made. So, you do need to be analytical, you need to have a certain level of analytical ability" (IV6).* Data management also emerged as a critical skill. Several participants highlighted challenges in maintaining accurate and consistent master data, particularly when updating or expanding ERP systems (IV1, IV5). One interviewee noted, *"Mastering and managing master data is very important, because when you want to add something new, you often find that a certain field in the ERP system or a specific data point is not well maintained" (IV5).* IV2 and IV8 also stressed the importance of data ownership and active involvement of employees in digital processes. While many respondents acknowledged that older professionals sometimes struggle more with data and digitalisation than their younger counterparts, digital literacy was described as a baseline requirement for modern PSM roles (IV1, IV3, IV4, IV5, IV6, IV8). *"Today's buyers need to have some digital knowledge; they must understand ERP systems and various software packages" (IV3).* Negotiation skills, although still vital, are evolving in nature (IV1, IV2, IV3, IV5, IV6, IV8). As one participant explained, *"Negotiation is a skill you should never lose. However, it does take on a different role" (IV2).* Similarly, supplier relationship management (SRM) continues to be highly relevant, evolving to be more relational, collaborative and fact-based as opposed to transactional in nature, adapting alongside digital transformation (IV1, IV5, IV7, IV8). Finally, several interviewees emphasised that the role of the PSM professional is becoming more strategic and expansive (IV2, IV4, IV6, IV8). They identify a shift from traditional procurement tasks to a broader, supply chain–wide perspective. *"Supply chain will become a much larger part of the organisation. I think we are shifting more towards supply chain professionals rather than just procurement professionals" (IV2).*

5. DISCUSSION

5.1 Augmentation and Proactive Risk Management in PSM

This study explored how augmentation, the collaboration between humans and digital technologies, supports proactive risk management in PSM by mitigating the cognitive constraints of bounded rationality (Colombo et al., 2023, p. 5; Edmunds & Morris, 2000, p. 18; Jones, 1999, p. 297; Leyer &

Schneider, 2021, p. 712; Simon, 1990, p. 15). It found that modern supply chain risks are increasingly caused by complex and fragmented data, as well as unpredictable events.

Firstly, the findings support existing theories that suggest technologies such as BDA, AI, and ERP systems can reduce cognitive constraints in human decision-making (Guo et al., 2025, p. 451; Harland et al., 2003, p. 54; Hartley & Sawaya, 2019, pp. 709-710; Kumar, 2022, p. 2; Mendes et al., 2022, pp. 1, 6, 10-11; Monczka; et al., 2022, p. 351; Peter, 2023, p. 42), such as emotional biases, limited knowledge and information overload (Edmunds & Morris, 2000, p. 18; Jones, 1999, p. 297; Leyer & Schneider, 2021, p. 712; Simon, 1990, p. 15). These tools enable earlier signal detection, pattern/trend recognition, planning, forecasting, and improved visualisation of complex datasets which in turn contributes to more effective proactive risk management (Harland et al., 2003, p. 54; Kumar, 2022, p. 1; Mendes et al., 2022, pp. 6, 10). However, while augmentation improves human rationality by enhancing access to structured and relevant data, the effectiveness of the technologies is highly dependent on data quality and input management (Chukwuani & Egiyi, 2020, p. 445; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5). Several interviewees highlighted that data must be clean, uniform, and well-maintained. A task that, as IV5 and Flechsig et al. (2022, p. 5) point out, is often still handled manually. Inaccurate or inconsistent data can result in biased AI outputs, effectively creating a new form of "digital bounded rationality". This aligns with the view of Leyer and Schneider (2021, p. 712) that AI offers effective decision making capabilities that can support or even replace human decision makers suffering from cognitive biases and limitations. The authors also caution that AI itself is not immune to bias, especially when trained on flawed data leading to unreliable tools, highlighting the importance of human oversight and high-quality data management in ensuring effective augmentation. This coincides with several sources that emphasise the crucial involvement of humans throughout the data management process (Isaza & Cepa, 2024, p. 2; Javaid et al., 2021, p. 71; Leyer & Schneider, 2021, p. 712).

Furthermore, while traditional tools like the ABC analysis and the Kraljic matrix remain valuable, the interviews reveal they are now often embedded within digital environments such as ERP systems (Chu et al., 2008, p. 841; Rozemeijer, 2022, pp. 109-110). An additional insight from the interviews concerns organisational structure. Larger organisations often operate with decentralised purchasing departments across multiple business units. This decentralisation allows teams to manage their own data and build tailored dashboards, while a central oversight department ensures consistency and alignment. This structure not only increases flexibility and mitigates bounded rationality but also acts as a proactive risk management mechanism by clarifying roles and segmenting responsibilities.

Moreover, this study illustrates that the potential of digital transformation requires a shift in professional competencies and skills such as analytical thinking, data management, systems thinking, and digital literacy are now essential for working with (Industry 4.0) technologies like Digital Twins, AI, and BDA (Bals et al., 2019, p. 6; Hallikas et al., 2020, p. 3).. For data management, interviewees stated that it is vital that companies ensure they are owners of the data. Employees should not distance themselves by claiming data management is not their responsibility, but instead actively engage in the digitalisation of processes as proactive risk management. This reflects the research of Delke et al. (2023, p. 13) and Vuchkovski et al. (2023, p. 10) that stress the importance of the roles "Master Data Manager" and "Data Analyst". On the other hand, traditional PSM capabilities, such as supplier relationship management (SRM), communication, and negotiation remain relevant. As Isaza and Cepa (2024, p. 2) note, digitalisation does not eliminate these skills but rather reshapes or transforms how they are applied. Interviewees explained that negotiation today is increasingly augmented, relational, collaborative and fact-based rather than transactional, largely due to the availability of technology and objective data. Emphasis is on long term relationships and collaborations between buyer and suppliers, aligning with Guo et al. (2025, p. 451) who underline the importance of supplier collaboration. Technology does not replace human strengths, it redefines them. These findings reinforce the definition of augmentation as a human-technology collaboration, and notion that digital transformation is a socio-technical process, reshaping not only technological infrastructure but also human roles and interactions (Fähndrich, 2023, pp. 11-12; Knudsen, 2020, p. 2). Interviews further suggest that PSM will embark on a more strategic path in the future. For instance, some interviewed companies now fully automate the creation of purchasing orders, which reflects Delke et al. (2023, p. 3) previously mentioned finding, that low-value tasks can be automated, freeing up human professionals to focus on strategic decisions (Yoo et al., 2010, p. 8)

Finally, this research addresses a gap in the existing literature by providing empirical evidence of how augmentation enhances proactive risk management in PSM. While much prior research has focused on operational or reactive use cases for digital tools, this study shows that technologies are already being applied in tasks such as supplier assessments, scenario forecasting, contract management, and quality control. These practices enable more strategic risk mitigation, demonstrating that digital augmentation is not just a support mechanism, but an enabler of proactive, resilient supply management. For a summarised overview, please refer to Figure 1 below

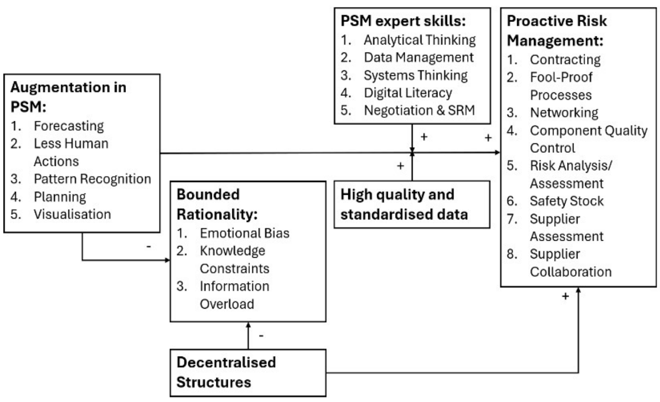

Figure 1 – Influence Diagram of Findings

5.2 Theoretical Implications

This study contributes to the literature by providing exploratory evidence how augmentation in PSM can overcome bounded rationality in proactive risk management. The findings confirm that digital tools improve risk detection, planning, and forecasting by enhancing access to structured and timely data. However, the study also highlights a critical limitation: the quality of outcomes is highly dependent on the quality of input data (Chukwuani & Egiyi, 2020, p. 445; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5). This introduces the concept of "digital bounded rationality", where flawed, biased or fragmented data can undermine the benefits of digital decision support (Leyer & Schneider, 2021, p. 712). As such, human oversight and data governance remain essential. The research further extends existing theory by demonstrating that digital transformation is not purely a technical process, but a socio-technical one. It reshapes how roles are distributed in organisations, how decisions are made, and how responsibilities are managed (Fähndrich, 2023, pp. 11-12; Knudsen, 2020, p. 2). In addition, the study provides academic evidence in interviews of the impact of decentralisation on both bounded rationality and proactive risk management. Finally, the study emphasises that effective augmentation requires a shift in professional capabilities. To benefit from technologies, PSM professionals need skills in data management, digital literacy, systems thinking, and analytical reasoning. Rather than replacing traditional skills like negotiation or relationship building, digitalisation changes how they are applied, making them more data-driven/augmented, collaborative, and strategic (Bals et al., 2019, p. 6; Chukwuani & Egiyi, 2020, p. 445; Delke et al., 2023, p. 13; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5; Guo et al., 2025, p. 451; Hallikas et al., 2020, p. 3; Vuchkovski et al., 2023, p. 10).

5.3 Managerial implications

Organisations should focus on leveraging Industry 4.0 technologies to support and enhance human decision making. To overcome bounded rationality, tools like AI, BDA, ERP systems and digital twins are most effective in proactive risk management when combined with human expertise. Therefore, training employees in digital tools and data interpretation is essential to exploit technological investments. Tools like Power BI-dashboards and data models can support early warning systems and improve the accuracy of risk identification, assessment and enable more adequate risk management actions as well as risk monitoring (Hallikas et al., 2004, p. 52). Among the many exhibitors at Digital Procurement World (DPW) in Amsterdam, "Creactives" stands out with its AI driven platform for PSM (DPW, 2025, p. 1). The company creates a Digital Twin of master and spend data, using AI to detect and eliminate errors. As Creactives puts it*: "We believe that poor data quality is the biggest obstacle to efficiency, automation, and digital transformation"* (Creactives, 2025, p. 1). By leveraging AI and Digital Twin technology, Creactives aims to deliver structured, harmonised, and continuously optimised data, directly addressing the data quality challenges highlighted by previous studies (Chukwuani & Egiyi, 2020, p. 445; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5). Seeing as data is essential, managers should foster a data-driven work environment. This also implies that the role of PSM professionals will evolve. A shift which requires upskilling in areas such as data management, analytical thinking, digital literacy and systems thinking. The PSM role is evolving from transactional procurement toward a more strategic, relational and collaborative function (Bals et al., 2019, p. 6; Chukwuani & Egiyi, 2020, p. 445; Delke et al., 2023, p. 13; Elouataoui et al., 2022, p. 19; Flechsig et al., 2022, p. 5; Guo et al., 2025, p. 451; Hallikas et al., 2020, p. 3; Vuchkovski et al., 2023, p. 10). Managers should adjust hiring, training, and role design with these cross-functional skills that complement the digital capabilities. While digitalisation can streamline information exchange and help to bring more automated supplier communications (e.g., through EDI/API), human relationships remain a core element of successful supply risk management. Strategic supplier collaboration, trust, and shared development continue to play critical roles in resilience (Guo et al., 2025, p. 451). Managers should pursue a hybrid approach to proactive risk management, using technology to enhance but not replace human interaction.

6. LIMITATIONS AND FUTURE RESEARCH RECOMMENDATIONS

This study offers insights into how digital technologies and human expertise interact within proactive risk management in PSM. However, several limitations must be acknowledged. First, the research is based on a small, purposively selected sample consisting of nine different respondents from eight companies with moderate to high digital maturity. While this allows for in-depth exploration, the findings may not be representative for all industries or organisations with different levels of digital adoption. Second, the qualitative and exploratory nature of the study introduces a degree of subjectivity. The reliance on participants' perceptions means findings may reflect personal or organisational biases. Additionally, there is no quantitative performance data, which limits the ability to objectively assess the impact of augmentation on proactive risk management in PSM. Third, the fast pace of technological change presents a challenge. Some of the technologies examined in this study, including those associated with Industry 4.0, may evolve rapidly, becoming standard or obsolete over time, potentially reducing the long-term relevance of certain findings. These limitations open opportunities for future research. The evolvement of PSM skill requirements and roles in augmented risk management may be further explored. Additionally, as AI takes on a greater role in decision making, issues of trust, ethics, and transparency become increasingly significant. Future research could explore the ethical implications of Industry 4.0 technologies, such as AI, and examine the evolving legal frameworks. Finally, as the influence of decentralised structures emerged as a new finding in the interviews, future research could further investigate their impact on proactive risk management. In short, while this study contributes foundational insights, future work is needed to deepen understanding, increase reliability and broaden applicability in this rapidly evolving field.

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With regard to the interviews, this study follows ethical guidelines to ensure participant safety, privacy, and autonomy. Interviewees were informed about the study's purpose and their right to withdraw at any point of time during the interview, with written and or verbal informed consent obtained beforehand. All data was anonymised, securely stored, and handled in line with data protection regulations. Sensitive topics were approached with care to prevent discomfort. These measures aimed to ensure a respectful and trustworthy research process.

Finally, ChatGPT was used during the writing of this thesis to assist in identifying and correcting language errors, such as grammar, spelling, and phrasing. The author remains solely responsible for the content and arguments presented in this thesis.

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APPENDIX

Appendix A – Interview Guide

Interview Guide
Introduction *Introduction of interview moderator*
Briefing ***Is it possible to record the interview?***
Toestemming tot interview vastleggen

Purpose of research / Purpose of interview / Explain the interview procedure

---

Question 1: ***Zou u zich kort kunnen voorstellen?***
Back-up:

- *Hoe lang werkt u als inkoper?*
- *Wat is uw rol als inkoper binnen dit bedrijf?*
- *Hoeveel ervaring heeft u met digitalisering binnen de inkoopsector?*

Outline question 2 from literature:
*Er bestaan verschillende soorten risico's binnen de context van purchasing and supply mangement zoals technische, commerciële, contractuele en uitvoeringsrisico's (Rozemeijer, 2022, pp. 91-92)**.** Vooral op moment van uitbesteding zien we dat bedrijven veel risico's en onzekerheden van tevoren in kaart willen brengen en te toetsen (Rozemeijer, 2022, p. 92). Dit kan bijvoorbeeld door de kans op het voordoen van een risico te toetsen tegenover de impact die het voordoen van een risico heeft op het bedrijf (Rozemeijer, 2022, pp. 92-93). Dit omschrijft een proactieve manier van denken waarmee er preventief wordt gehandeld om negatieve impacts op de prestaties van het bedrijf te voorkomen (Monczka; et al., 2022, p. 351). Echter kan het gebeuren dat een risico zich uiteindelijk toch voordoet. Hierop handelen, wordt reactief risicomanagement genoemd en heeft als doel de schade en negatieve gevolgen voor bedrijfsprestaties te beperken (Monczka; et al., 2022, p. 351).*

Question 2: ***Hoe wordt er binnen uw organisatie omgegaan met risico's, zowel vóórdat ze zich voordoen (P) als nadat ze zich voorgedaan hebben (R)?***

Question 2a: Hoe werkt jullie risico-identificatie fase en herkennen jullie toekomstige onzekerheden? Een voorbeeld: what-if scenarios.

Question 2b: Hoe beoordelen jullie risico's? Voorbeeld: toetsen van risicowaarschijnlijkheid tegenover impact

Question 2c: Hoe handelen jullie ten opzichte van risico's? Voorbeeld: risico-overdracht door contracten, risico-acceptatie, risico-eliminatie, risico-reductie of word er dieper geanalyseerd.

Question 2d: Hoe bewaken jullie en monitoren jullie op risico's? Voorbeeld: hoe werden trends, nieuwe risico's en veranderende omstandigheden gevolgd?

Outline question 3 from literature:
Supply chains zijn door de tijd heen complexer geworden door toenemende globalisering wat lijdt tot een toenemende mate aan supply risico's (Christopher & Peck, 2004, p. 1). Deze complexiteit van supply chains zorgt er tegelijkertijd voor dat een groot volume aan informatie en datapunten voor verschillende doeleinden beschikbaar gesteld kan worden(Seyedan & Mafakheri, 2020, p. 2). In theorie biedt dit de kans om meer weloverwogen beslissingen te nemen, maar in de praktijk zien we dat dit niet altijd het geval is. Zo zorgt het ervoor dat methodes zoals Total Cost of Ownership en Life Cycle Costing niet altijd worden toegepast omdat het simpelweg teveel tijd zou kosten om alle data mee te nemen in besluiten (Christopher et al., 2011, p. 69). Hierdoor kunnen risico's over het hoofd worden gezien of te laat worden ontdekt om adequaat op te reageren.

Question 3: ***Wat maakt het lastig om risico's op tijd te herkennen of er goed op te reageren wanneer ze zich voordoen?***

Question 3a: Krijgt u altijd voldoende werkbare informatie om een goede beslissing te nemen?
Back-up: Is het soms lastig om door de hoeveelheid informatie te filteren wat relevant is?
Question 3b: De supply chain kan behoorlijk complex zijn, met verschillende partijen en variabelen die invloed kunnen hebben op risico's. Hoe gaat u om met het analyseren van risico's als er zoveel variabelen meespelen?

Outline question 4 from literature:
Supply chain-data is dus complex en omvangrijk. Gezien de cognitieve grenzen van de mens, is het niet mogelijk om al deze data in korte tijd te analyseren en vervolgens de jusite conclusies te trekken. Er zijn wel middelen die kunnen helpen in soortgelijke situaties(Seyedan & Mafakheri, 2020, p. 2). Zo kunnen 'Industry 4.0' technologieën worden ingezet om zeer veel data te verzamelen en te analyseren. Denk hierbij aan Internet of Things en Cyber-Physical systems die verschillende fysieke apparaten (sensoren, machines, omgevingsfactoren) verbinden aan digitale netwerken. Deze grote hoeveelheid data kan vervolgens geanalyseerd worden door middel van Big Data analysis en AI (Moretto et al., 2017, p. 4; Tatini & Pub, 2025, p. 4).

Question 4: ***In hoeverre speelt digitalisering een rol bij het proactief en reactief managen van risico's?***

Question 4a: Welke digitale middelen of systemen gebruikt u momenteel om risico's te voorkomen? te monitoren en te beheersen?

Back-up: Denk aan zogenoemde Industry 4.0 technologieën die worden ingezet, bijvoorbeeld Artificial Intelligence (AI), Big Data, Internet of Things and Services, Cloud Computing en Cyber Physical Systems.

*Question 4b**:** Welke digitale middelen of systemen gebruikt u momenteel om risico's te beperken/beheersen als zij zich hebben voorgedaan?*

Outline question 5 from literature:
We zien dat Industry 4.0 technologieën verschillende positieve werkingen kunnen hebben. Het kan leiden tot een hogere mate van transparantie in supplychains wat meer weerbaarheid tot gevolg heeft (Liu et al., 2024, p. 1165). Ook kan transparantie zorgen voor meer flexibelere markten wat er voor zorgt dat er sneller kan worden gereageerd op plotselinge storingen of onderbrekingen in de markt (Schiele et al., 2022, p. 6). Daarnaast kunnen er door middel van voorspellende analyses, track en trace technologie, en big data analysis risico's worden herkend of vermeden zoals vraag-gerelateerde risico's, supply-time risico's en andere supply risico's (Ivanov et al., 2019, pp. 11-12).

Question 5: ***Welke kansen kunnen technologieën bieden om reactief en proactief risicomanagement te optimaliseren?***

*Question 5a**:** Wat is volgens u het belangrijkste voordeel van technologie voor risicomanagement?*
Question 5b: Hoe kunnen technologieën worden toegepast op het identificeren van risico's? VOORBEELD: Zo bestaat er software die leveranciers beoordeeld op hun risico wat zorgt voor meer supply-chain transparantie (Titan & MineSpider).
Question 5c: Hoe kunnen technologieën worden toegepast op het beoordelen van risico's? VOORBEELD: zo bestaat er software die levaranciers live monitort en toetst. (Contingent & Integrity Next),
Question 5d: Hoe kunnen technologieën worden toegepast op het omgaan met risico's? VOORBEELD: Contractmanagement software wat risico-overdracht makkelijker maakt (Brooklyn Solutions) of risicodashboards d.m.v. Power BI.
Question 5e: Hoe kunnen technologieën worden toegepast op het monitoren van risico's. VOORBEELD: Zo bestaat er software die automatisch 'risk-alerts' geeft en data over verschillende matrix evalueert (Prewave & Pulse Market).

Outline question 6 from literature:
Elke inkoper heeft vaardigheden en competenties nodig die aansluiten bij zijn of haar functie. Een functie kan meerdere rollen omvatten, en iedere rol stelt specifieke eisen aan de benodigde vaardigheden (Jones, 2013, pp. 116-117). Er zullen ook rollen zijn die een nieuwe set vaardigheden nodig hebben om digitale middelen effectief toe te passen (Zeisel, 2020, p. 8). Zo beschrijven verschillende studies dat I4.0 en digitalisering zullen leiden tot een behoefte aan andere vaardigheden dan voorheen (Delke et al., 2023, p. 13).
Question 6: ***Welke competenties zijn volgens u nodig om technologie effectief te gebruiken in risicomanagement?***
Question 6a: Is er bepaalde kennis of vaardigheden nodig om goed met Industrie 4.0 technologieën te werken?
Question 6b: Welke vaardigheden zullen volgens u in de toekomst onmisbaar zijn als het gaat om risicomanagement in een steeds digitalere omgeving?

Appendix B – Written Informed Consent Form

Toestemmingsformulier voor Deelname aan Onderzoek

Onderzoekers:
Thomas Pas, Universiteit Twente
Nathan Rotmans, Universiteit Twente

Doel van het onderzoek:
Dit onderzoek richt zich op de impact van digitalisering op zowel proactief als reactief risicomanagement binnen inkoop en supplymanagement (Purchasing & Supply Management/PSM). Uw bijdrage levert waardevolle inzichten voor academisch onderzoek.

Duur van deelname:
Het onderzoek bestaat uit één semigestructureerd interview van ongeveer 45 tot 60 minuten.

Vrijwillige deelname:
Uw deelname is volledig vrijwillig. U kunt op elk moment stoppen met het interview of uw toestemming intrekken, zonder opgaaf van reden en zonder nadelige gevolgen.

Risico's en belasting:
Er zijn geen bekende fysieke of psychologische risico's verbonden aan deelname, afgezien van de tijdsinvestering.

Voordelen:

Hoewel er geen direct persoonlijk voordeel is, draagt uw deelname bij aan wetenschappelijke kennis over digitale transformatie in de publieke sector.

Vertrouwelijkheid:
Alle informatie die u deelt, wordt vertrouwelijk en anoniem behandeld. Persoonlijke gegevens worden verwijderd uit de transcripties en publicaties. De data worden veilig opgeslagen en zijn alleen toegankelijk voor het onderzoeksteam.

Opname van het interview:
Het interview wordt geluidsopgenomen voor transcriptiedoeleinden. U kunt ervoor kiezen om niet opgenomen te worden.

Gebruik van citaten:
Geanonimiseerde citaten uit het interview kunnen worden gebruikt in publicaties of presentaties die voortkomen uit dit onderzoek.

Verklaring van toestemming
Door dit formulier te ondertekenen verklaart u dat:

- *U voldoende bent geïnformeerd over het doel en de opzet van het onderzoek;*
- *U vrijwillig instemt met deelname aan dit interview;*
- *U weet dat u op elk moment kunt stoppen zonder consequenties;*
- *U toestemming geeft voor het gebruik van geanonimiseerde citaten in publicaties;*
- *U toestemming geeft voor het opnemen van het interview (indien van toepassing).*

Naam deelnemer: _______________________________________

Datum: ____

Handtekening deelnemer: ________________________________

Handtekening onderzoeker T. Pas: ______________________________

Handtekening onderzoeker N. Rotmans: ______________________________

Appendix C – Verbal Informed Consent Form

Mondelinge Instemming voor Deelname aan Onderzoek

Voordat we beginnen met het interview, wil ik graag uw mondelinge toestemming opnemen.

U heeft het toestemmingsformulier ontvangen, gelezen en hopelijk ondertekend. Zoals daarin staat, neemt u deel aan één interview van ongeveer 45 tot 60 minuten. Uw deelname is vrijwillig. U kunt op elk moment stoppen of uw antwoorden intrekken, zonder gevolgen.

Het interview wordt opgenomen om nauwkeurig uitgeschreven te kunnen worden. Alles wat u zegt wordt anoniem en vertrouwelijk behandeld. Citaten uit het interview kunnen worden gebruikt in publicaties, maar uw naam of andere identificeerbare gegevens zullen daarbij worden weggelaten.

Door deze opname en uw mondelinge bevestiging geeft u aan dat:

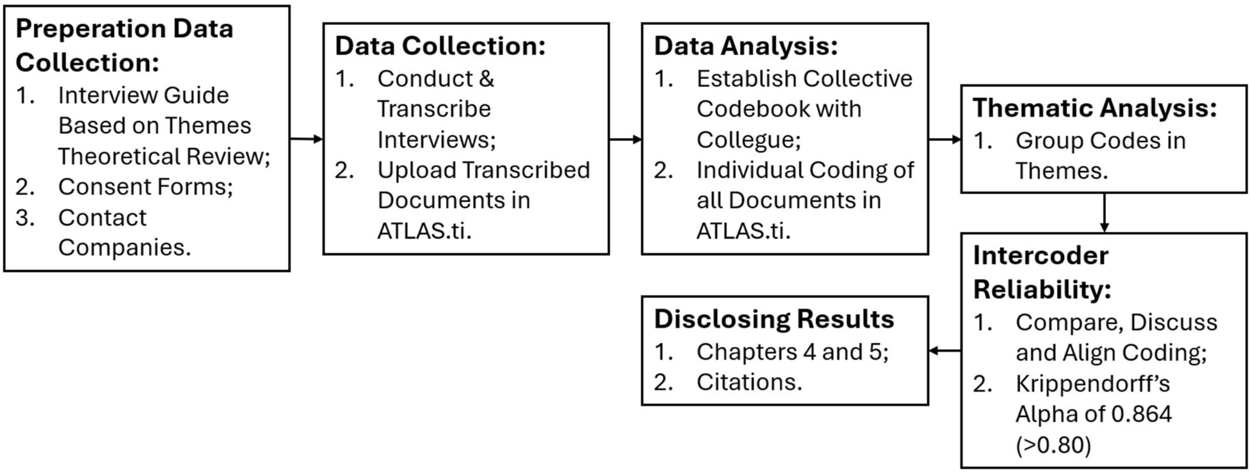
- *U goed bent geïnformeerd over het doel en de inhoud van het onderzoek;*
- *U vrijwillig instemt met deelname;*
- *U begrijpt dat u zich op elk moment kunt terugtrekken zonder gevolgen;*
- *U akkoord gaat met opname van het interview en het gebruik van geanonimiseerde citaten in publicaties?*

Heeft u op dit moment nog vragen?"

(Wacht op reactie)

Als u akkoord gaat met deelname onder deze voorwaarden, wilt u dat dan nu mondeling bevestigen voor de opname?

Appendix D – Stepwise Visualisation of the Research Process



Appendix E – Cross-Case Comparison table

Theme	Code/interview (IV)	Definition Code Based on Interviews	Example Quote	IV 1	IV 2	IV 3	IV 4	IV 5	IV 6	IV 7	IV 8
T1: Bounded Rationality	T1.1 - Unpredictability	Events that do not follow a clear pattern, making outcomes impossible to reliably anticipate or control (e.g. wars, politics, pandemics).	*"The war in Ukraine, for example. You can have all the technology in the world, but I do not believe anyone could have predicted exactly how this conflict would unfold" (IV5).*	X	X		X	X	X		X
	T1.2 - Data complexity	The difficulty of managing and interpreting large volumes of fragmented, inconsistent, and changing data across supply chains. It often results from poor standardisation, scattered sources, and the need for advanced tools to make reliable decisions..	*"There is not really a funnel for purchasing or supply chain to make a decision. He [a purchaser] has to get many sources to really bring those data points to a workable risk analysis" (IV2).*	X	X		X	X	X	X	X
	T1.3 - Data Quality	How accurate, consistent, and usable data is. Poor quality leads to errors, mistrust, and rework, while good quality enables reliable analysis and decision-making.	*"The quality of your data really is the fundament for these kind of [digital] activities" (IV8).*	X	X			X	X	X	X
T2: Digital Applications	T2.1 – Artificial Intelligence (AI)	AI supports forecasting, spend analysis, and price trend insights. Tools like HGS and Key Result help connect data, but results depend on data quality and human input. AI offers suggestions, but human judgment is still crucial.	*"If they can bring this together with AI or something like that, it could already make a good decision for you. Maybe even better than when I see all those little data points and try to make sense of them. I think that's where the future is heading" (IV2).*	X	X	X		X	X		
	T2.2 – Big Data Analysis (BDA)	BDA, and more specifically PowerBI, is widely used to make complex data more accessible and actionable. It helps visualise trends, monitor supplier performance, manage stock, and track certain goods. Manual data cleanup is still often needed. AI and analytics tools support forecasting and risk analysis but depend on good data quality.	*"You can analyse complex data more quickly and ultimately extract valuable information from a whole lot of data faster" (IV1).*	X	X	X	X	X	X	X	X
	T2.3 – Digital Twin	A Digital Twin is a virtual replica of a physical product or process, used for product simulations.	*"For our most important product, a Digital Twin has been designed in which not a single component is the same as in the original and with a completely different supply chain channel. This is to prevent the risk of not being able to deliver it" (IV4).*				X				X
	T2.4 – EDI/API	EDI/API are integrated communication tools that connect ERP systems with suppliers to automate order sending, confirmations, and data exchange.	*"Then the system sends everything from one PO [Purchase Order] to suppliers and there is even the possibility to 100% auto PO. Then you do not need an operational buyer to place purchase orders" (IV1).*	X			X				
	T2.5 – ERP	An ERP system (e.g. SAP) is the company's core software that manages orders, forecasts, inventory, and risk. It centralises data, tracks supplier reliability, and connects machines and processes. Challenges include data quality, system setup, and integrating multiple data sources consistently.	*"the ERP system is the heart of the company. Risks are saved in this system and are also more visible that way" (IV3).*	X		X	X	X		X	X
	T2.6 – Sensors	Sensors collect real-time data from machines to improve safety, monitor performance, and prevent errors. They help track ships, machine use, output, and maintenance needs. While sensor investments can be costly, they support automation and Industry 4.0 goals, making operations easier and more efficient.	"*That [an AIS sensor] is a sensor that indicates where in the world a ship is located and also displays other information about the voyage" (IV2).*	X	X	X					X
T3: Digital Benefits	T3.1 – Forecasting	Forecasting involves using data to predict customer demand and adjust inventory accordingly. With supply chain engineers and AI models, forecasts become more accurate by linking various data sources and analysing trends. Continuous monitoring of supply risks helps adjust	*"If you see that there are hiccups three months before it needs to arrive with me, then I know I have to start taking action now and not wait until three months or two and a half months later" (IV8).*	X	X		X				X

		safety stock and react early to potential disruptions. Forecasts are updated regularly in ERP systems, enabling better planning and timely decisions across the supply chain.									
	T3.2 – Less Human Actions	Automating some parts of processes to reduce manual input and errors. Systems like ERP, EDIs/APIs, and sensors communicate directly, triggering actions automatically, like starting machines, updating stock, or placing orders. This saves time, improves quality, cuts human mistakes, and boosts efficiency. Digital tools reduce dependency on people and enable faster, smarter decisions.	*"I think integrated systems like EDI, API, and Product Lifecycle Management systems ensure that data stays up-to-date and reduce dependence on human intervention" (IV4.)*	X	X	X	X		X	X	
	T3.3 – Pattern Recognition	Pattern recognition uses tools like Power BI and AI to spot trends in data, such as price changes, sales patterns, or product demand. These insights help teams identify seasonal products, detect shifts early, and adjust inventory or purchasing strategies accordingly. By comparing past and current data, companies can better predict future needs and improve decision making.	*"You see a trend. For example, you know that next year you unexpectedly have too much PRODUCT to sell, and that was also the case the year before or earlier—you can get all that from systems. So basically, you already know next year: be careful, maybe buy a little extra at a good price (IV6)."*	X			X		X		X
	T3.4 – Planning	Planning is about managing inventory and resources to avoid downtime by anticipating needs, adjusting schedules when delays occur, and using data to optimise capacity and stock. This ensures the right parts are available when needed.	*"You could also ask: Do I really have a problem, or is there something else I can already start with? For example: I may not have everything complete, but I do have this part. Or, I need this specific component later in the process. Can I start anyway? Right now, the default is: It's not complete, so we do not start. But you can start shifting that mindset, as long as the right information is available" (IV2).*	X	X				X	X	
	T3.5 – Product Tracing/Mapping	Tracking every product and its components throughout production and supply, using systems to identify batches, link parts to finished goods, and monitor where and when issues occur. This ensures quality control and quick response to defects.	*"The most important items are given a unique code during production, allowing us to trace which production batch they were part of and identify other potentially faulty production codes" (IV4).*	X	X	X		X		X	
	T3.6 – Visualisation	Tools like Power BI create clear, interactive dashboards that present complex data in an simple way. This helps to spot trends, track KPIs, monitor supplier performance, and make informed decisions quickly. Visualisation improves data transparency across departments, supports proactive actions, and enhances planning and efficiency.	*"Visualisation is extremely important, really, really important. For example, we now have a constantly updated dashboard" (IV6).*	X	X		X	X	X	X	X
T4: Proactive Risk Manage-ment	T4.1 – Contracting	Setting clear agreements like SLAs and collaboration contracts to manage risks, liabilities, and responsibilities across the supply chain. It provides trust, confidentiality, and proactive risk management. Proper contracting helps protect all parties and supports smooth cooperation.	*"You can see we increasingly try to capture things in SLAs and cooperation agreements to make sure liability and risks related to components can be passed on appropriately, from assembly all the way through to the sales side. For example, when it comes to warranty periods" (IV1).*	X	X	X	X				X
	T4.2 – Decentralisation	Distributing responsibility for data management and Purchasing across various business units and departments. Each unit or team manages its own specific data and purchasing needs through dedicated dashboards, while a central team oversees coordination and consistency across the entire firm. This approach balances local control with overall alignment to ensure accurate data, risk management, and cost allocation.	*Every business unit has its own decentralised purchasing department" (IV4).*	X			X		X		X
	T4.3 – Fool-Proof Processes	Prevent human errors by using safeguards like sensors, digital assistants, automated checks, and clear instructions. This results in correct process runs even if mistakes are made.	*"we increasingly solve that risk by simply making it fool-proof. Essentially taking as many measures as possible so that the*	X					X		X

			operator or whoever is working with the machine basically cannot make a mistake" (IV2).								
	T4.4 – Local Sourcing	Purchasing components and materials from suppliers located nearby. This improves speed, flexibility, and problem-solving, especially when quality issues arise. While offshore sourcing (e.g., from Asia) was once cost-effective, there's now a shift toward reshoring due to global supply chain disruptions.	*"We have about 80% of suppliers within an hour around our plant, so someone can quickly go there with a trailer or van and solve the problem" (IV1).*	X	X					X	
	T4.5 – Networking	Maintaining strong, industry-specific relationships with experts, suppliers, and account managers to stay informed about market changes early. This early access to information helps anticipate risks and respond faster than competitors.	*"If you have good contacts in certain branches, you are often the first to know because they see developments daily [...]it allows you to handle quicker than others" (IV1).*	X	X						
	T4.6 – Quality Control Components	The process of ensuring that all parts meet standards before and during production. This includes supplier testing (e.g. functional and end-of-line tests), limited internal checks, and monitoring failure patterns.	*"We draw conclusions during production; we don't have 100% incoming inspections. We trust suppliers to ensure the quality of components, we only check quantities" (IV2).*	X	X	X	X				X
	T4.7 – Risk Analysis/Risk Assessment	A structured, data-driven approach to identifying, evaluating, and prioritising potential risks in the supply chain, such as component failure, supplier dependency, and delivery delays. Tools like ABC, Kraljic or FMEA analyses as well as PowerBI dashboards and heatmaps can be used.	*"Of course, there are also other mechanisms like the Kraljic matrix and similar tools, which you can use to categorise products or determine which quadrant a product falls into" (IV5).*	X	X	X	X	X	X		X
	T4.8 – Safety Stock	A buffer inventory of components or products kept on hand to prevent stockouts due to demand fluctuations or supply delays. It is calculated using data on lead times, usage rates, and risk levels, and helps maintain operational continuity during disruptions.	*"The size of the safety stock can be determined based on the data points the supply chain provides. You really need to continuously measure the lead times of all your products, especially critical ones. Doing this manually takes a lot of effort. The only way to manage it effectively is by using systems to help" (IV1).*	X	X		X		X		X
	T4.9 – Supplier Assessment	A structured evaluation of suppliers based on criteria like delivery reliability, product quality, ISO certifications, financial health, and audit performance. It helps identify risks, maintain standards, and support sourcing decisions through tools like approved supplier lists, periodic audits, and benchmark reviews.	*"These parties are all audited on various aspects before we contract them, and they continue to be audited periodically on those same aspects. This includes quality, supply chain management, ISO standards, and information security" (IV4).*			X	X	X			X
	T4.10 – Supplier Collaboration	A strategic partnership between buyer and supplier focused on mutual development, open communication, trust, and shared (long-term) goals. It includes co-development of products, EDI/API, transparency in risk and pricing, and frequent communication to proactively solve issues and improve performance together.	*"We look at where suppliers' development is going within the next 10 years and how that fits with new machine developments, so joint development can be done" (IV1).*	X	X	X	X	X		X	X
T5: Skills	T5.1 – Analytical Thinking	The ability to interpret and use data to understand processes, identify improvements, make informed decisions, and proactively manage risks in supply chain and business operations.	*"You do have to be able to see something when you look at data. You also need to be able to recognise where improvements can be made. So, you do need to be analytical, you need to have a certain level of analytical ability" (IV6).*	X	X		X	X	X		X
	T5.2 – Computer Literacy	The ability to use digital tools, software systems (like ERP), dashboards, and AI technologies to perform tasks, analyse data, and communicate within a modern, tech driven work environment.	*"Today's buyers need to have some digital knowledge; they must understand ERP systems and various software packages" (IV3).*	X		X	X	X	X		
	T5.3 – Data Management	The systematic control and maintenance of master data, ensuring data are accurate, complete, and up-to-date. This could contribute to reliable analysis and decision making.	*"Mastering and managing master data is very important, because when you want to add something new, you often find that a certain field in the ERP system or a specific data point is not well maintained" (IV5)*	X				X			

	T5.4 – Negotiation	Reaching agreements by combining relationship management with data driven insights, shifting from traditional hard bargaining to more collaborative, fact-based discussions.	*"Negotiation is a skill you should never lose. However, it does take on a different role" (IV2).*	X	X	X		X	X		
	T5.5 – Personal Skills	Important personal skills include critical thinking, proactivity, collaboration, communication, quick decision making, practical insight, and the ability to recognise and respond quickly to risks and opportunities.	*"You need to be a bit quicker in your thinking now, I think. Be able to respond faster to things. Make quick decisions and spot opportunities and risks quickly and just reacting to them swiftly as a company" (IV6).*		X			X	X	X	
	T5.6 – SRM	A strategic approach to building and maintaining long term, collaborative partnerships with suppliers. It focuses on trust, communication, and sharing relevant data to negotiate deals based on facts, rather than just personal relationships. SRM aims for mutual benefits and sustainable outcomes.	*"Traditional negotiation is ultimately about closing a deal through relationship management and negotiation, based on your underlying parameters. The relationship and the background information are what, I believe, truly enable you to close the deal" (IV8).*	X				X		X	
	T5.7 – System Thinking	Understanding and analysing the entire supply chain as an interconnected system. Looking at all parts from raw materials to end product, to anticipate risks, improve processes, and make better decisions based on data.	*"Supply chain will become a much larger part of the organisation. I think we are shifting more towards supply chain professionals rather than just procurement professionals" (IV2).*		X		X		X		X