



CHALMERS
UNIVERSITY OF TECHNOLOGY



Understanding Organizational Learning in Technology Development and Implementation

A case study of how organizational learning could be strengthened in one of Sweden's largest manufacturing companies

Master's thesis in Supply Chain Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

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Abstract

Organizational learning has in past research shown to play a critical factor for companies seeking to maintain competitiveness. While research has developed different models and frameworks to support learning processes, organizations still face challenges in capturing, sharing and utilizing knowledge effectively. At the same time, emerging technologies are reshaping industrial contexts which put an increasing focus on the importance of how technology development and implementation processes can facilitate organizational learning and competitive advantage. This study, which was conducted at one of Sweden's largest manufacturing companies explores how organizational learning in the context of manufacturing technology development and implementation can be better understood and strengthened.

The study is based on a qualitative approach that combines unstructured and semi-structured interviews, internal document analysis and observations and insights from the daily organizational environment. The material was analyzed through the lenses of the SECI model, the 4I framework, single-loop and double-loop learning and theories on exploration and exploitation.

The findings from the case company showed that even while learning takes place locally and within networks, mechanisms for knowledge sharing and coordinations of learnings are limited for reaching cross-functional organizational learning. This leads to duplicated learning and knowledge not being captured in usable formats. Identified barriers from the study were lack of time, unclear roles, limited awareness of who to involve and initiatives remaining within isolated organizational levels. The study contributes to research on organizational learning by highlighting the gap between formal learning structures and actual practices in complex industrial organizations. It further suggests that strengthening organizational learning requires improved integration, visibility and coordination of existing structures and learning activities.

Keywords: Organizational learning, Knowledge sharing, Manufacturing industry, Technology development, Technology implementation, Cross-functional collaboration.

Acknowledgements

This master thesis was conducted during the spring of 2026 as the concluding project of the master's programme Supply Chain Management at Chalmers University of Technology. The project has provided us the opportunity to approach challenges from an engineering perspective and apply our knowledge into real-life situations.

First and foremost, we would like to sincerely thank our supervisor from Volvo, Lena Moestam and our university supervisor, Carl Wänström. Both of you have made this thesis project a valuable opportunity for us to further develop our knowledge while encouraging us to explore new perspectives and think critically throughout the process. We sincerely thank you for your support, guidelines and expertise that have helped to form this project.

We would also like to express our gratitude for all the participants who took the time to be interviewed and contribute to valuable insights. Your insight and willingness to share diverse perspectives really helped us to form the outcome of this study. We are sincerely grateful for their contributions and guidelines in this project.

Finally, we would like to express our gratitude towards our families and friends. We are grateful for your support and encouragement throughout this project as well as during our years at Chalmers University of Technology.

Hanna Ekvall and Medina Salihovic, Gothenburg, June 2026

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List of Abbreviations

Below is the list of abbreviations that have been used throughout this thesis listed in alphabetical order:

BVR	Business Value Realization
CoC	Center of Competence
LTS	Local Technology Specialist
MTM	Manufacturing Technology Manager
MTRM	Manufacturing Technology Roadmap
MTS	Manufacturing Technology Specialist
TTI	Trucks Technology & Industrial Division

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1

Introduction

The purpose of this section is to get a better understanding of what the scope of this study will cover. The section will start with covering the background and the aim of why this study is being conducted and what the expected results are. Furthermore, it will also cover which research questions will be analyzed and which limitations will narrow down the scope of this study.

1.1 Background

In today's fast growing and globalized markets, organizations face an increasing need to learn and innovate to remain competitive and succeed (Chiva et al., 2014). For several decades, scholars have argued that both the individual and organizational learning can enable growth and the achievement of sustainable competitive advantages over time (Yuan and Chayanuvat, 2021). Furthermore, research has shown that organizational learning contributes to improved organizational performance and greater adaptability to sudden market changes. The process not only aims to improve organizational knowledge and ways of thinking (Real et al., 2012), but also to encourage and enable innovation and the generation of new ideas within the organization (Chiva et al., 2014). According to Basten and Haamann (2018), organizations with well functioning learning processes are better prepared to understand their environment and make more accurate decisions. Organizational learning could therefore be described as a continuous driven process that fosters the development of core competencies within the organization (Real et al., 2012).

Despite the benefits highlighted in research, several challenges may hinder organizations from fully achieving effective organizational learning. Organizational learning is often seen as a complex process in which learning can be slowed down or even completely disrupted if challenges occur within this continuous driven process (Yuan and Chayanuvat, 2021). Common challenges that may have this impact on the learning process include organizational structures, power dynamics, culture and management style. Furthermore, Crossan et al.(2011) describes organizational learning as a process that must constantly integrate multiple dimensions, namely the individual, group and organizational level while at the same time handling barriers associated with each level. This suggests that organizational learning should not only be considered at one level, but rather the interaction between the different levels within the

organization. In addition, Basten and Haamann (2018) argue that although much of past research has demonstrated the importance of having a good organizational learning, many organizations struggle with the actual implementation of organizational learning. One reason for this, as presented by the authors, is that the concept of organizational learning is perceived as theoretical and lacking clear guidelines on how to effectively achieve organizational learning. This implies that even if theory is available there is still a gap for organizations to understand how to actually apply and achieve organizational learning in practice.

In light of these findings, it could be argued that effective organizational learning enables the corporations to attain valuable market position compared to its competitors. However, as presented, there are several challenges that an organization may encounter when striving to become, or further develop as learning organizations. By understanding the challenges companies face and applying relevant theories to address them, organizations may improve their ability to develop into learning organizations. As highlighted by Chiva et al. (2014), many organizations are moving towards globalization and need to understand how to innovate and learn more effectively in order to succeed. In terms of innovation, technology development could be presented. Technology development has shown to significantly affect an organization's way of operating by providing the possibility of delivering improved product quality, efficiency and innovation in manufacturing operations (Thomas, 2024). Technologies such as robotics, internet of things, artificial intelligence and automation have in a short period of time become essential for a more competitive operational environment in terms of being able to produce and deliver products more efficiently. By using advanced technology in the production operations could therefore result in improved productivity and gaining valuable market positions. Therefore, it is essential to get a deeper understanding of how a global enterprise could operate and benefit from achieving organizational learning in the context of technology development in the manufacturing operations. One such enterprise that could provide valuable insights is Volvo Group.

1.2 The Case Company

Volvo Group is one of the world's leading companies in developing and manufacturing buses, construction equipment, engines, and trucks. The company employs approximately 102 000 people, operates 14 different brands, serves 180 markets and has production activities in 17 different countries. Within Volvo Group, a department referred to as Trucks Technology & Industrial Division (TTI) has the overall responsibility for all production of the Volvo, Renault and Mack Trucks but also the engines, transmission and spare parts that are provided to Volvo Groups customers. Furthermore, the division works with optimizing logistics and the entire supply chain for all of the brands in the TTI organization.

TTI is a major division that spans both the local and the global levels, including all production plants worldwide within the truck's scope. The global perspective focuses on establishing and maintaining a unified framework to ensure alignment

across all plants. Within this role, the global level contributes with new insights and technological developments that can be adopted and utilized by individual sites. Within the division, the local perspective focuses on each plant as an independent unit, where each plant has the autonomy to initiate actions and make decisions within the scope and guidelines established on the global level. Each factory has the autonomy to determine whether new technology should be implemented, based on its specific needs and available resources.

In the context of a large organization, built up by several functions, there are many development activities going on simultaneously. This can create strengths in terms of common development of industrial standards. However, capturing and effectively utilizing the learnings generated within such a large organization is often challenging. In addition, the decentralized structure with autonomy for different sites requires a delicate balance between top-down implementation of solutions and the encouragement of bottom-up improvement initiatives. A further challenge in the organization, related to the difficulties of capturing learnings, is that work often gets duplicated, and that there are missed opportunities for coordination of efficiency and cost saving potential.

1.3 Aim

The aim of this study is to provide an understanding of how organizational learning within TTI may be strengthened within the existing manufacturing technology process. The study seeks to enhance the understanding of what challenges are present in terms of organizational learning and why these challenges arise throughout the process. Understanding the challenges related to learning in the existing manufacturing process within the TTI division may create opportunities to address them, potentially reduce their impact, and strengthen organizational learning.

1.4 Research Questions

RQ 1 How is organizational learning in the manufacturing technology process intended to function, and how is it enacted in practice?

RQ2: Why do these gaps between the intended and enacted practices occur?

RQ 3: How can these insights contribute to the strengthening of organizational learning in the manufacturing technology process?

1.5 Scope of Study

The study will be conducted at the TTI division which enables an in depth examination of knowledge sharing processes and organizational learning practices within a specific defined organizational context. The research will be limited to only covering parts of the full Volvo Group scope and the findings will therefore be heavily

influenced by this selection. Furthermore, the scope will primarily focus on the manufacturing technology process and how coordination of knowledge sharing can play a critical role in this process. The selection of empirical focus was guided by the TTI request, in which the organization highlighted existing challenges related to the coordination of learning. Therefore, the finding will to some extent be influenced by this direction, putting more emphasis on certain technology contexts compared to others. Important to note is that the study does not aim to cover the indepth technical implementation details, rather keeping a focus on understanding why organizational learning is not effectively coordinated within these implementations.

2

Theory

The following section will present the literature study conducted including descriptions of different theory models and frameworks relevant for the concept of organizational learning. The section will start with a definition of what organizational learning is, setting the baseline for the study. This will be followed by theories targeting multiple aspects of organizational learning, such as knowledge creation and transfer, learning flows, balancing innovative and efficient development, as well as how deeply an organization chooses to reflect on the learnings.

2.1 Organizational Learning

Organizations are continuously learning, however, without a systematic approach, the learning process may be ineffective and could potentially lead to misleading conclusions (Basten & Haamann, 2018). Organizational learning could be explained as a continuous driven process in which individuals within an organization create and distribute knowledge across the company (Real et al., 2012). It can be further conceptualized as the development of systematic approaches that illustrate how organizations can improve their learnings (Basten & Haamann, 2018), including processes that adapt or update rules, mental models and knowledge (Chiva et al., 2014). The organizational learning process opens the possibility of developing and maintaining new knowledge that can support the understanding of different aspects within the organization, linking closely to possible impacts on performance (Chiva et al., 2014) and development of core competencies within the organization (Real et al., 2012).

According to the definition of organizational learning, it connects to both knowledge creation and knowledge sharing. Cristache et al. (2025) argues that only possessing knowledge within an organization is not enough in today's market, rather that the value and gaining competitiveness from the knowledge relies on how companies utilize it to their advantage. Yeboah (2023) argues that an organization that has a well-developed knowledge sharing process could generate higher productivity, faster problem solving, and more competitive advantages in the market. Furthermore, Karim and Ahmad (2019) demonstrate that knowledge sharing has an overall beneficial effect on individual and team learning, which in turn has been proven to improve various organizational performance. Shared knowledge helps employees

improve their performance by executing tasks and solving problems more efficiently.

Despite the importance of organizational learning to organizational performance it does not occur automatically. Organizations must constantly engage with the multiple dimensions of learning, as well as handling its related barriers (Crossan et al., 2011). Effective organizational learning thereby requires intentional and ongoing efforts. As emphasized by several authors, it is a cyclical and continuous process, meaning that learning cannot be achieved once and then considered complete, instead it must be sustained and reinforced over time (Crossan et al., 1999; Nonaka, 1994, Real et al., 2012).

2.2 Organizational Knowledge Creation

In past research, organizational knowledge creation has shown to play a crucial role for companies seeking to stay competitive in today's market (Kahrens & Früauff, 2018). Organizational knowledge creation is described as a process where the individual's knowledge is being shared and connected to the company's joint system. The aim is to ensure that the individual knowledge, such as behaviors, ideas and thoughts, are available for others in the organization. Furthermore, the creation of knowledge is explained as a continuously driven process in organizational learning that relies on the integration and interaction between explicit and tacit knowledge (Basten & Haamann, 2018; Kahrens & Früauff, 2018).

2.2.1 Explicit and Tacit Knowledge

Knowledge is created through continuous interaction between explicit and tacit knowledge which result in new ideas and insight to the organization (Kahrens & Früauff, 2018). Individuals in an organization may form ideas regarding a certain matter, but the ideas are further developed through constant interaction and dialogues. Explicit knowledge is described as knowledge that is created and shared through words, manuals and documentations (Nonaka, 1994). It builds on past learnings that have been stored and documented in a sequential way. Comparing explicit knowledge to tacit knowledge, it can be found to be generally more structured and clear to generate. In contrast, tacit knowledge is in many circumstances difficult to document due to the nature of the knowledge (Oranga, 2023). Tacit knowledge builds on the idea that knowledge is created through personal experience and the specific situation in which the learning has been generated from (Nonaka, 1994). Tacit knowledge has proven to be of high value in the learning, making it important for organization to focus on. If the organization can capture the knowledge efficiently, overcoming the challenges of formulating and documenting the specific knowledge, it can enable better and more accurate decision making (Oranga, 2023).

There is a constant relation between explicit and tacit knowledge, and as presented by Kahrens and Früauff (2018), explicit knowledge can be transformed into tacit knowledge over time. When individuals use the explicit knowledge through documentation, the knowledge becomes less explicit and more tacit. The reason for this is

that the individual develops experience and generates a person based understanding. Such knowledge is built by executing tasks, working, and interacting with others, which ultimately results in the development of their own, new tacit knowledge.

In contrast, Nonaka (1994) presented how hidden tacit knowledge could be turned into explicit knowledge. This transition is according to the author enabled through metaphors, which help the individuals understand something by comparing it to something else. The process of understanding through metaphors is related to psychology, where most of an individual's thinking relies on intuition and imagination. By analysing the situation through examples or other similar domains, instead of using the exact feature, the individual can understand the situation more quickly and with less effort. Metaphors are seen as a crucial aspect in creating knowledge as it opens the possibility of connecting different ideas together. This can both strengthen the understanding if the ideas are aligning, but it can also create contradictions. Common for both is that this process may result in new learnings being developed. However, metaphors may sometimes be considered unclear. The need for logical and organized thinking is seen as an important aspect when creating new learnings. Analogy helps to ensure that the creative ideas generated from metaphors are being clear, organized and logically developed. The aim is to show how the two different ideas may share similar aspects. Overall metaphors could be understood as a step that allows for creative and free thinking while analogy is a step that aims to ensure the thinking is more logical and clear, moving towards explicit knowledge.

Conceptualization of how the individuals gain and transform explicit and tacit knowledge in an organization is seen as an important aspect when aiming to understand how knowledge is created and shared in an organization (Kahrens & Früauff, 2018). Nonaka (1994) presents that generating new knowledge and using it effectively in an organization could be achieved through the interaction between tacit and explicit knowledge. This process is described as the four modes of knowledge creation theory or also referred to as the SECI model.

2.2.2 SECI Model

The socialization, externalization, combination and internalization (SECI) model aims to describe how knowledge can be created and transferred within an organization (Kahrens & Früauff, 2018). Furthermore, the model aims to illustrate the interaction between tacit and explicit knowledge, by examining how individuals in an organization switch between the two forms of knowledge. The four steps in the SECI model could be summarized as a continuously repeating a cycle or spiral, where the knowledge is gradually moving from the individual, to different teams and then lastly to the whole organization, see Figure 2.1.

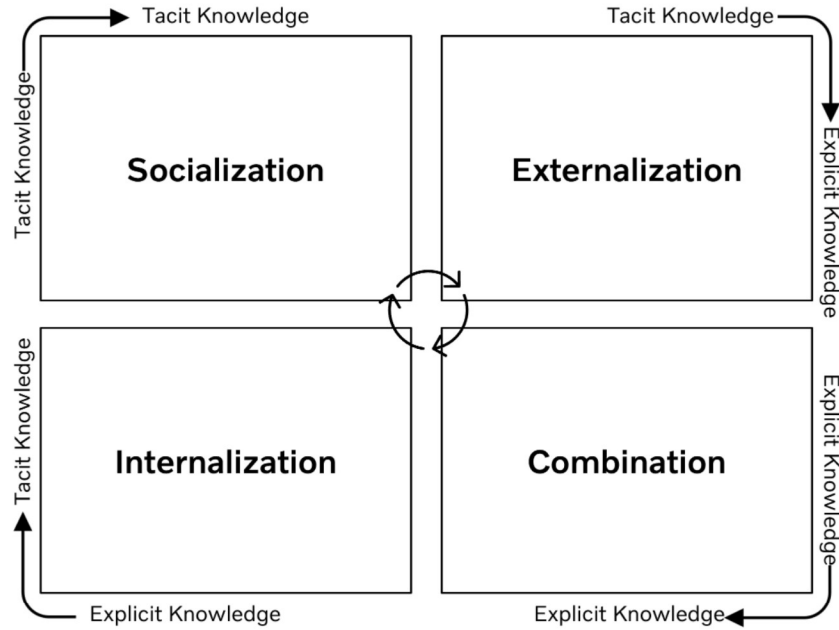


Figure 2.1: Knowledge creation theory model based on and adapted from Nonaka and Konno (1998).

2.2.2.1 Socialization (Tacit→Tacit)

In socialization, learning is mainly carried out through observation (Basten & Haarmann, 2018). Nonaka (1994) presents that tacit knowledge could be learned through close interactions with others instead of reading manuals. This approach becomes effective since tacit knowledge is connected to specific situations and is difficult to formulate in documents. Building on Nonaka (1994), Kahrens and Früauff (2018) further suggests that tacit knowledge can be understood through personal experience and interaction with others that can provide examples. One example of this is where a newly hired employee often spends more time with an experienced worker to gain valuable insight through close interaction but also questioning and practicing the tasks. Over time, this sharing of valuable experience among individuals can contribute to that knowledge becoming embedded into the organization's routines.

2.2.2.2 Externalization (Tacit→Explicit)

Externalization involves the process of turning tacit knowledge into forms that are understandable to others (Nonaka & Konno, 1998). In the externalization phase tacit knowledge aims to move and become explicit knowledge. The phase aims to share the individual insight to a group which results in the knowledge becoming the team's collective knowledge. The creation of new knowledge is carried out through sharing experience and discussing with others in the organization in order to build combined knowledge (Kahrens & Früauff, 2018). Furthermore, clearly describing knowledge that is considered as hidden and difficult may be achieved through models, examples or comparison. This results in that the individuals in the organization

may express and share their experience directly to the group.

2.2.2.3 Combination (Explicit→Explicit)

The combination phase aims to turn existing explicit knowledge into more systematic explicit knowledge (Nonaka & Konno, 1998). The aim with the combination phase is to gather, modify and connect the information in order for the knowledge to be applicable in different situations (Kahrens & Früauff, 2018). To work with this process, Nonaka and Konno (1998) present three process steps of importance. The first process step is to collect information e.g. reports and data, and then combine the information into a coherent form. The second step regards that the knowledge should then be shared throughout the organization, e.g. through meetings or presentations. The third step concerns processing or editing the knowledge and then making it usable through documents or reports. By following these three steps a successful combination phase could be achieved.

As indicated by the three steps, accessible formats of documentation are of high importance for the phase to proceed (Nonaka & Konno, 1998). Databases and communication systems are examples of how to store and share knowledge within the organization (Kahrens & Früauff, 2018). Furthermore, in order for the combination phase to be effective, the individuals in the organization must communicate. The communication could happen through group discussion or meetings. The complexity in this phase is when the number of groups or departments increase. To handle this concern structural meetings and discussion forums may be a guideline to ensure organized knowledge transfer.

2.2.2.4 Internalization (Explicit→Tacit)

Internalization aims to convert the newly explicit knowledge to tacit knowledge (Nonaka & Konno, 1998). In this phase, the individual recognizes which knowledge is applicable and useful in their domain within the organization. In order for the individual to understand and recognize which knowledge is applicable, they must understand their role in a large organization. Furthermore, Nonaka and Konno (1998) presents that training and learning through experience opens the possibility for individuals to learn from the teams but even from the whole organization. The aim with the internalization step is to ensure that the individual does “learning by doing” until it becomes a natural part of that individual’s way of working. Simulations, on the job training, experiments and learning by doing are examples of methods that may be applicable when the individuals test what they have learned and adapt it to their real practice (Kahrens & Früauff, 2018).

2.2.3 Drivers of Organizational Knowledge Creation

Constant interaction between different individuals in an organization is seen as a crucial aspect when developing new ideas (Nonaka, 1994). Knowledge creation starts at the individual level, and for it to benefit the organization, factors such as commitment, motivation and willingness become important for the development of

new ideas. Furthermore, to extend these benefits beyond the individual level the ability of the organization to support and share these insights is critical.

Going deeper into the individual factors, Nonaka (1994) presented three factors that encourage commitment. The first factor is intention, which regards that the people act based on purpose and interpret the knowledge based on their own goals and values. This implies that different people with different intentions may perceive the same knowledge differently. The second factor is autonomy which refers to ensuring that the individuals can act freely and make decisions independently. The idea builds on that when individuals in an organization work independently, new ideas and thoughts may emerge. This opens the possibility to encourage creativity and motivation which in turn may result in new insights for the organization. The third factor is fluctuation, which refers to changes or unexpected events. Unexpected situations often result in interrupting the individual's normal routines which leads to questioning their practice and habits. When fluctuation occurs, individuals must in most cases rethink their way of working and hence develop new ideas in order to handle the situation. Having disruptions helps individuals question old beliefs and develop new ones. The three factors, intention, autonomy and fluctuation are seen as drives for ensuring that the individuals in an organization develop commitment which in turn result in deeper thinking and new knowledge in an organization.

In addition, organizational culture is seen as an important aspect for sharing knowledge (Kahrens & Früauff, 2018). A culture that is built up on shared values and beliefs enables a more effective knowledge sharing, as well as incentives to promote commitment among individuals. The SECI model is highly based on the ideas of Japanese culture, which emphasizes learning through reflections, teamwork and continuous improvements. For other cultural contexts the model may need to be adapted to make it applicable and effective.

2.3 4I Framework for Organizational Learning

The 4I framework of organizational learning developed by Crossan et al. (1999) provides a foundational perspective on organizational learning as a dynamic, multi-level and process-based concept. Building on early research regarding aspects of how learning takes place within organizations, such as the insights on exploration and exploitation, collective learning, and the creation and transfer of knowledge, the framework aims to integrate these insights into a more comprehensive model. The framework highlights that organizational learning is not a linear process with a sole focus area, instead it can be understood as the continuous interactions between individual perceptions, collective interpretations, and organizational structures.

The framework explains organizational learning as a process that occurs across multiple levels through four interconnected processes. The four processes are intuiting, interpreting, integrating and institutionalizing, which all together link the individual, group and organizational levels of learning together. Through these processes, organizations can develop individual insights into shared understandings and pro-

duce learnings that can be embedded within organizational systems and routines (Crossan et al., 1999). However, while the framework is influential and widely cited in the domain of research, later reviews by Crossan et al. (2011) suggest the function to remain as a framework rather than a fully developed theory. The authors argued that there are still several gaps in the research regarding the mechanisms underlying organizational learning, particularly how learning processes are casually connected and under what conditions learning takes place.

2.3.1 Levels of Learning

At the core of the 4I framework, is the idea that organizational learning is structured across three levels: individual, group and organization (Nielsen et al., 2018; Crossan et al., 1999). Overviewing the different levels, the individual level emphasizes that learning originates from personal mental processes shaped by experience (Crossan et al., 1999). Moving further to the group level, the learning emerges through shared interpretations and coordinated interactions across levels. At the organizational level, learning becomes embedded in systems, routines, and structures that continue over time, even as individual members or groups change.

The framework further highlights that the different levels should be seen to be interdependent, and that regardless of the levels being described as structurally distinct, they are functionally inseparable. Crossan et al. (1999) presents clearly how different levels are associated with particular learning processes, but that organizational learning occurs through the interactions and spillovers between levels. The boundaries between levels in practice are hard to identify, but the focus on all levels should be emphasized as learning cannot be fully understood or achievable by examining the levels separately.

2.3.2 Core Learning Processes

In addition to the multi-level perspective of learning, the second part that can be classified as the foundation of the 4I framework are the four interconnected learning processes: intuiting, interpreting, integrating and institutionalizing (Nielsen et al., 2018; Schulze et al., 2013; Crossan et al., 1999). These processes demonstrate how learning progresses, by examining how individual insights are transformed into organizational knowledge through a structured process (Crossan et al., 1999). Figure 2.2 presents a simplified overview of the 4I processes and their relation to the different levels of learning, which will be further introduced in the following sections.

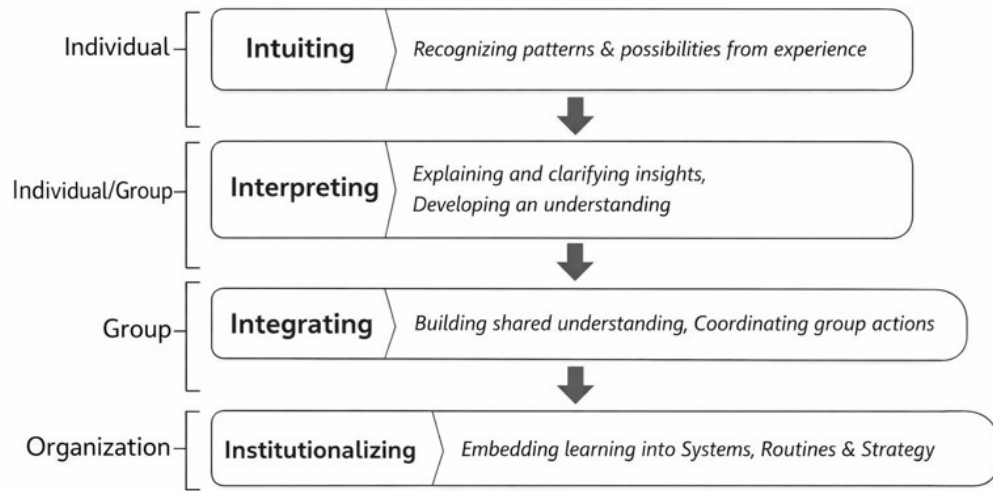


Figure 2.2: The 4I framework shows how learning progresses from individual intuition, through interpreting and group integrating, to organizational institutionalizing.

2.3.2.1 Intuiting

The first process, intuiting, occurs at the individual level and refers to the ability to recognize patterns or possibilities based on personal experience (Crossan et al., 1999; Schulze et al., 2013). The authors explain this as primarily a subconscious process, where the subconscious mind is seen as the major driver in generating new insights, contrasting the traditional views of learning, defining it as more analytical (Crossan et al., 1999). The pattern recognition in this process often takes place in two different forms, namely expert intuition and entrepreneurial intuition. Common for both forms of intuition is that they form the starting point for new learning within the organization.

Going deeper, expert intuition is based on accumulated experience, where exposure to similar situations over time helps the individual to develop the ability to recognize patterns rapidly and almost automatically in familiar situations. The challenge with this type of intuition is however that the knowledge often becomes tacit, implying difficulties in articulating and transferring the knowledge to others. In case of recognition of this type, it is common that experts cannot fully explain their decisions since the reasoning has become embedded and unconscious (Crossan et al., 1999; Schulze et al., 2013). In contrast, entrepreneurial intuition is more future-oriented and innovative (Crossan et al., 1999). This type of recognition is characterized by early connections between unknown areas and identification of op-

portunities that have not previously been recognized. This distinction can be further understood through the perspective of exploration and exploitation, where expert intuition shares many connections to exploitation and entrepreneurial intuition with exploration.

A central challenge of both types of intuition processes is that the outcomes are often preverbal or nonverbal, where the individual may have a sense of what could be done or explored but lack the language to explain it both on a personal and interpersonal level. As a result the intuitive insights are difficult to share, limiting their impact beyond the individual level. To minimise or bridge the gap and helping individuals to interpret and express their insights the authors suggest introducing tools such as imagery and metaphors (Crossan et al., 1999). A further challenge arises from the process itself which is characterized by uncertainty and unpredictability. In the early phases of new ideas on the individual level, the insights cannot be evaluated as correct or incorrect instead they mainly represent possibilities rather than confirmed knowledge. Whether these insights lead to successful outcomes depends on the progress of the process, defining how they are further developed and integrated as learning processes.

Crossan et al. (1999) further emphasizes that intuiting is shaped by both prior experience and involvement in a problem. As a general part of the process, new ideas often appear after working on an issue for a longer period of time and then taking a step back, which allows ideas to develop in the background. The authors also caution that attempting to analyze or explain an idea too early can hinder or interrupt its development.

2.3.2.2 Interpreting

The second process, interpreting, focuses on explaining and making sense of insights or ideas. It represents the transition from subconscious intuition to conscious understanding. With the processes starting at the individual level, the aim is to clarify and articulate insights using familiar language and connect it to a known context. Through the process of interpreting, the individuals develop cognitive maps, helping them make sense of the domains in which they operate. As presented in the framework, Crossan et al. (1999) highlights that the process of interpreting is highly dependent on the context in which the individual operates, as well as how experience plays an important role in how different cognitives maps evolve. Different levels of experience within a domain affects the ability to perceive patterns differently where more experienced individuals developing more sophisticated cognitive maps. At the same time these cognitive maps shape how individuals interpret new information leading to different ways of receiving and filtering data based on past experiences. All of these aspects together introduces the challenge of equivocally which can be explained as information having multiple, sometimes conflicting meanings. Important to note is that this challenge is not directly related to poor quality of information, but rather the coexistence of different interpretations.

As the process continues, the existence of multiple interpretations leads the pro-

cess into becoming a social process of communicating the individual interpretation further to the group (Crossan et al, 1999; Schulze et al., 2013). Through communication, dialogue and shared language, individuals interact to ensure that ambiguity is reduced and that the group starts to build a common understanding of the insights. As indicated by the description of the process, it occurs at the intersection of the individual and group levels and links these levels together (Crossan et al, 1999).

2.3.2.3 Integrating

The third process, integrating, can be found on the group level and involves the further development of the insights formed in earlier stages (Crossan et al.,1999; Schulze et al., 2013) . In this process, the aim is to ensure that insights are shared and coordinated among group members (Crossan et al.,1999). Compared to interpretation, which can be summarized as making sense of an insight, primarily individual level but also towards group level, the process of integration aims to align multiple interpretations into one collective understanding and coordinate this specific understanding with the group.

The process of integrating develops through ongoing interaction, where dialogue and group discussions are highlighted as important success factors for aligning interpretations into a shared understanding. A central part of this process is to work with the creation of a common language, as it enables collective sensemaking, as well as it also preserves the existing knowledge within the group. This is important for the organization's ability to adapt and renew over time, as the shared language is something that needs to be continuously evolving for deeper learning to occur (Crossan et al., 1999).

For the group to work with the process of integrating there are multiple aspects highlighted as important by Crossan et al. (1999). The first is that there are different types of communication, where not all are found to be equally effective to reach a shared understanding. For example, dialogue between individuals in a group is seen as the preferred way of communicating, as it enables the group to develop more nuanced shared understanding compared to lighter communication forms. The authors emphasize that engagement on a deeper level is crucial, as the group otherwise risks reaching consensus without critical reflection of the insights. Furthermore, the effectiveness of the process is also context driven, meaning that the social and practical environment in which learning takes place becomes of high importance. For example, much of the process of integrating occurs within everyday work practices, or communities of practice, where knowledge can be developed in a relatively informal way (Crossan et al., 1999). One type of this informal sharing practice is storytelling. Storytelling is an important part of the learning as it often reflects real-world practices easy to refer to, and when the stories develop over time, they help build a deeper shared understanding supporting better problem solving. In this way, stories become part of the group's shared knowledge (Weick & Robers, 1993).

2.3.2.4 Institutionalizing

The final process, institutionalizing, is the process where learning becomes embedded into the organizational practices (Crossan et al., 1999; Schulze et al., 2013). This implies that instead of having individual insights or informal group practices, the learning is captured in organization-wide systems, structures, routines and strategies (Crossan et al., 1999). During this process, the focus is on creating a lasting framework for the organization that guides organizational behaviour and future actions even if members come and go. Crossan et al. (1999) also highlights this final step as especially important for mature organizations, where patterns of behaviour and communication begin to stabilize. For mature organizations, these patterns are or can be included in formalized practices, which allows the organization to store and re-use knowledge. This all together ensures that the organization can leverage the learnings and use it as guidance for future direction.

However, Crossan et al. (1999) further argues that this shift in processes also changes the nature of learning. The previous focus on spontaneous insights, instead becomes structured processes such as plans and formal procedures with less focus on the continuous development. If or when these plans prove successful, they most often become standardized routines. To further manage and operate these routines, organizations need mechanisms to both monitor current performance and to challenge them to reflect on future possibilities. This is often achieved through diagnostic systems and interactive systems. Diagnostic systems are primarily control mechanisms, which manage learning by monitoring performance against predefined goals, ensuring consistency and reinforcement of established routines or best practices. In contrast, interactive systems are often designed to stimulate ongoing development by putting attention to emerging uncertainties, encouraging engagement with information and reconsidering assumptions. This highlights the continuous tension between exploiting existing institutionalized knowledge and exploring new learnings which was introduced by March (1991).

Another challenge presented by Crossan et al. (1999) is that the process of institutionalization cannot capture all ongoing learnings as the environment constantly changes which in turn leads to a lag between what organizations have learned and what they need to do. This often leads to a gap between existing routines and current demands and if not balanced, this often results in organizations heavily relying on individual initiative and informal learning to allow for quicker adaptation.

2.3.3 Learning Flows

Organizational learning is according to the 4I framework described as a continuous and evolving process that spans across levels. Expanding the framework further, Crossan et al. (1999) also highlights learning as a process moving in two directions, not only a one-way transfer. The different flows are referred to as feed-forward learning and feedback learning.

Feed-forward learning describes the process of how new insights and ideas originate

at the individual level and move upward through the 4I core learning processes presented in previous sections. This flow of learning supports innovation and strategic renewal. In contrast, feedback learning has the opposite flow, where existing organizational knowledge shapes how individuals or groups understand the organization and also guide the behaviors. According to Crossan et al. (1999) these processes happen simultaneously, creating an ongoing tension which can be examined through deep diving into how learning shifts between levels.

One challenge highlighted by Crossan et al. (1999) is the transition from interpretation to integration. Moving from the individual level to group understanding requires individuals to find ways to express and communicate tacit knowledge, making it explicit to allow for shared understanding. However, even when ideas are made more explicit, it does not guarantee a shared understanding. Within this process, real alignment is only confirmed through coordinated action. Furthermore, it is emphasized that for situations with new insights, experimentation can be more effective than discussion alone in building shared understanding. Another challenge highlighted is the relation between institutionalization and intuition. Establishing rules, procedures and standardized ways of working tend to reinforce existing ways of thinking and make it difficult to question or deviate from them, risking new intuitive insights to be suppressed.

Looking at organizational learning as a dynamic flow between levels and processes further allows for identification and analysis of bottlenecks. Just as for other flows, even organizational learning can be constrained by factors such as the organization's ability to absorb and integrate new ideas. When too much new insights or learning is generated but cannot be incorporated, it may become stuck at different levels, creating frustration and disengagement if not handled correctly. Understanding how these flows are enabled or constrained in the specific context is important for understanding how the organization learns and renews over time (Crossan et al., 1999). For example different organizational factors such as formal systems and structures, can either support or hinder the flow of learning. Figure 2.3, illustrates the possible flows of learning across levels, and thereby also the levels of which bottlenecks can occur.

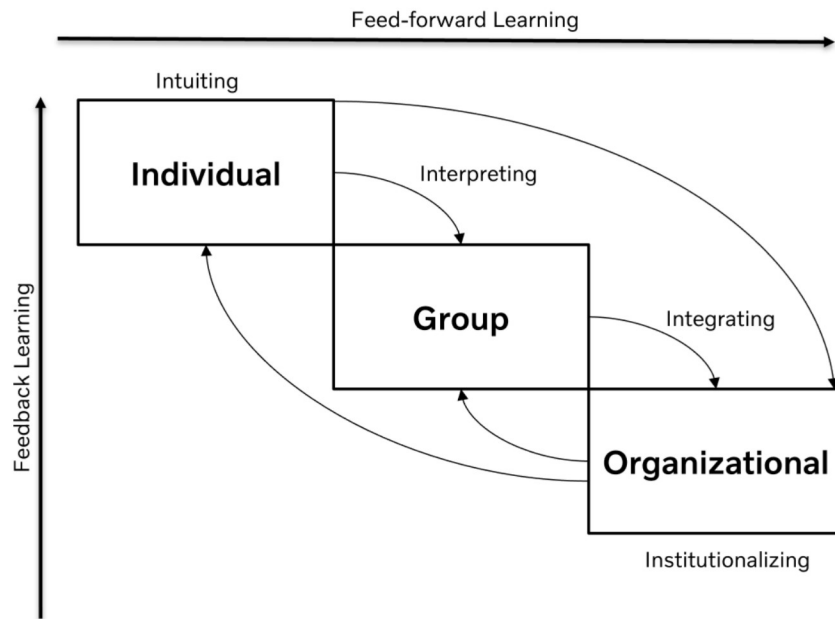


Figure 2.3: 4I framework as a dynamic learning flow across levels based on and adapted from Crossan et al. (1999).

As found, Crossan et al. (1999) presents feed-forward and feedback learning processes as a dynamic learning cycle, however later research suggests that empirical studies have struggled to empirically capture these bidirectional flows (Crossan et al., 2011). Instead much of the focus has been to isolated levels or outcomes, overlooking the complex, multilevel and often nonlinear interactions that actually drive learning across organizations.

2.3.4 Enabling Learning Across Boundaries

The original 4I framework indicates that organizational learning is not solely a structural or cognitive process, instead it is also a process highly dependent on social, contextual and relational dynamics (Crossan et al., 1999). Building on this foundation, later extensions emphasize additional factors that influence how learning unfolds across levels, moving focus from only how learning flows to also examine why these processes either succeed or break down (Crossan et al., 2011).

A major contribution to the framework highlighted by Crossan et al. (2011) is the integration of power, politics and emotion as important factors to organizational learning. As argued by Lawrence et al. (2005) these factors act as drivers for learning across levels since the progression of ideas throughout the 4I processes depends highly on who supports them and how people influence others to accept or support the idea. The authors bring several examples relating to the 4I process of the framework on how these factors become important for organizational learning. For example, at the intuiting stage, individuals are strongly affected by how organizational systems such as training or culture influence and shape experiences

and identities, influencing which insights emerge. During interpretation, the dynamics and possibility to persuade, use expertise and social skills to get others to accept ideas directly shape the learning. The process is also dependent on other social power dynamics, where individuals may choose to share or withhold ideas depending on political dynamics or fear of negative consequences. Moving further to the integrating stage, authority and control restrict which alternative that becomes coordinated, and which insights are sidelined. When insights move towards institutionalization, power determines which ideas become embedded into systems and standard procedures. The authors further emphasize that power and politics should not be seen as something negative, rather it is a natural and important part of learning that can deeper explain why insights are shared or not. Complementing this perspective, Vince (2001) also emphasizes the role of emotions such as anxiety, envy and enthusiasm as part of how individuals choose to engage or avoid insights as part of the learning process.

Another factor introduced in later extensions is the importance of leadership to the organizational learning process (Crossan et al., 2011). Leadership can be found to have a role in enabling or constraining learning across all levels of the organization, where for example leaders influence learning at the micro level by encouraging individuals to experiment and build a readiness to learn (Very & Crossan, 2004). At the meso level, they instead shape communication patterns and knowledge-sharing networks within the group, and at the macro level by selecting, legitimizing and embedding knowledge into organization-wide systems. Another aspect highlighted by the authors is how different leadership styles play an important role for different types of learning. The authors argue that transformational leadership tends to promote exploration and innovation, whereas transactional leadership instead tends to support more effective exploitation and refinement of existing knowledge. The focus on leadership becomes important as it influences both if learning occurs and also decides what kind of learning that takes place. Overall, these extensions broaden the 4I framework by highlighting that organizational learning is a complex process that needs to balance power dynamics, emotions, leadership and contextual influences to effectively achieve learning across all levels and processes.

2.4 Exploration and Exploitation

At the core of organizational learning lies a fundamental tension namely the need to maintain what already works while also developing new possibilities. The organization's ability to balance and manage these two activities simultaneously is commonly referred to as the concept of organizational ambidexterity (Raisch & Birkinshaw, 2008). Organizations must use the accumulated experience and established routines to operate efficiently, while innovation and exploration of unfamiliar domains is important for long term adaptability and competitiveness (Crossan et al, 1999). As part of organizational research, the topic of organizational ambidexterity has become an increasingly important topic over the years, introducing several key concepts and contributions.

March (1991) was among the first to address the tension between continuity and change and further conceptualised it as the challenge of managing between exploration and exploitation. Exploration refers to the pursuit of new knowledge or possibilities through activities such as search, experimentation, and risk taking as enablers of variation, discovery, flexibility, and innovation. Exploitation, in contrast, focuses on refining and using existing knowledge through activities such as refinement, selection, efficient production, and implementation and execution of established knowledge. In relation to the concepts, understanding the balance between the two becomes essential for organizations to avoid being trapped in rigid or suboptimal patterns. As indicated by March (1991), systems that concentrate on exploration at the expense of exploitation tend to incur the high costs of experimentation without realising its benefits. Conversely, organizations that focus predominantly on exploitation risk being trapped in stable yet suboptimal conditions limiting their ability to adapt to new opportunities important for long-term survival and success. Balancing exploration and exploitation is however a complex challenge because the two activities compete for the same limited resources and their benefits differ in size, predictability, timing and distribution across and beyond the organization. Organizations must make explicit choices, such as investment decisions and strategy, as well as implicit choices embedded in structures and practices. In addition, resources must also be allocated efficiently and with regard to both short- and long-term outcomes, comparing different organizational units and accounting for risks.

Comparing exploration and exploitation on a more detailed level, it can be found that exploration is inherently more uncertain, remote in time and diffuse in its consequences compared to exploitation. It comes with a variety of difficulties such as weighing between what is good in the long run and how these benefits may only be appearing in that time horizon, how priorities and focus areas can vary across time, and how initiatives can affect different organizational units differently, and perhaps even have consequences for broader systems. In contrast, exploitation generally generates faster, more certain, and direct and locally observable feedback, which reinforces current activities. As a result, the process naturally favors exploitation, since each increase in competence increases reward for continuing the activity, producing cumulative advantages. Over time, this phenomenon can lead to path dependence, creating a situation where both the local unit and the network can be locked into suboptimal routines, where competence in inferior activities prevents emphasis on superior, unfamiliar alternatives (March, 1991).

2.4.1 Typology of Organizational Ambidexterity

As part of the research examining how organizations structure and manage the balance between exploration and exploitation, Kassotaki (2022) highlights that the concept can be understood through two key dimensions. The first dimension is the time dimension which refers to whether exploration and exploitation occur simultaneously or sequentially over time. The second is the space dimension, which determines whether ambidexterity takes place within the same organizational unit or across independent or interdependent units. By combining these two dimensions in

different ways, authors such as Simsek et al.(2009), further developed into Kassotaki (2022), present four main types of organizational ambidexterity, each reflecting distinct strategies for balancing exploration and exploitation activities. The four types are: contextual ambidexterity, structural ambidexterity, cyclical ambidexterity and reciprocal ambidexterity.

2.4.1.1 Contextual (Harmonic) Ambidexterity

Contextual ambidexterity, or also referred to as harmonic ambidexterity, describes an organizational context that pursues a simultaneous focus on exploration and exploitation within the same unit. Through this context, the unit develops the capacity to achieve both states of alignment in current objectives and adaptability to adjust and respond to emerging opportunities (Gibson & Birkinshaw, 2004; Simsek et al., 2009). This approach can be found inherently challenging due to competition of limited resources. Such competition can cause internal contraindications and potential conflicts, as well as inconsistent ways of working (Simsek et al., 2009). However, in a supportive organizational context, this approach can enable more effective innovation than when exploration and exploitation activities are structurally separated (Gianzina-Kassotaki, 2017), since the connection to daily operations is strong (Simsek et al., 2009).

Research done within contextual ambidexterity highlights several important preconditions for success. A central requirement emphasized is a supportive organizational context which can effectively balance between high performance expectations and social and psychological safety (Gibson & Birkinshaw, 2004; Simsek et al., 2009). Organizational practices such as flexible work structures, job enrichment and reflection (Simsek et al., 2009) along with leadership that focuses on and emphasizes autonomy and adaptability (Gibson & Birkinshaw, 2004; Simsek et al., 2009) help employees to make informed decisions on balancing short-term efficiency with long-term adaptability.

2.4.1.2 Structural (Partitional) Ambidexterity

Structural ambidexterity, or also in some research referred to as partitional ambidexterity, is characterized by an organizational structure that separates exploratory and exploitative activities. In this setup there are different units responsible for pursuing distinct strategies, and the approach overall relies on structural differentiation and integration (Huang & Kim, 2013; Kang & Snell, 2009; Simsek et al., 2009). The different units operate with different incentive systems, cultures and have management structures tailored to the respective activity. Important to highlight is however, that although these units operate independently, they remain interdependent and coordinated through senior management oversight, overall company strategic vision and knowledge integration mechanisms to balance competing demands (Simsek et al., 2009). As found through a case analysis performed by Huang & Kim (2013), one of the main benefits of structural ambidexterity is that the approach enables firms to balance competing demands, respond effectively to changing environments, while at the same time allowing for a dual focus on both short- and long-term growth. It is

further emphasized that since structural ambidexterity is formally embedded in the organization's structure, it can be particularly suitable for large or complex organizations where clear separation and coordination is required in order to successfully balance between exploration and exploitation.

As indicated by Simsek et al. (2009), a clear intent and shared vision among senior leaders is one of the most crucial pre-conditions for structural ambidexterity to result in benefits. It is of high importance that there is a valuation of both exploration and exploitation equally, as well as the ability to handle paradoxes and foster collaboration and open debate.

2.4.1.3 Cyclical (Punctuated Equilibrium) Ambidexterity

Cyclical ambidexterity, or also may be referred to as Punctuated Equilibrium, is characterized by organizations that focus on exploitation over a long period of time and occasionally switch to exploration for a short period of time within the same unit (Kassotaki, 2022). Cyclical ambidexterity aims to not do exploration and exploitation at the same time but rather switching over time (Simsek et al., 2009). The idea builds on the theory called Punctuated equilibrium. Punctuated equilibrium is a theory which emphasizes that long periods of stability are interrupted by major changes that occur in a short period of time (Gersick, 1991). The concept surrounding punctuated equilibrium may help organizations to understand and manage change by knowing that changes do not often occur steady but rather may emerge quickly after a long period of stability. Simsek et al. (2009) explains that the same unit handles exploration and exploitation but at different times. This in turn leads to attention and resources are being shifted back a fourth within the unit. Organizations need to understand that having cyclical ambidexterity will result in repeating shifting between exploration and exploitation. This in turn will likely result in changes in procedures, structure and resource allocation. Furthermore, communication and managing conflict are other important aspects that need to be considered in this ambidexterity. Cyclical ambidexterity also requires flexibility and a fundamental understanding of when to move between exploitation and exploration (Kassotaki, 2022).

Innovation and especially new product innovation are closely linked to cyclical ambidexterity (Simsek et al., 2009). The ideas built on that exploration helps to discover new technology insight which in turn may result in new industrial changes. Exploitation aims to take the new learnings in order to improve the products through better processes. Firms with strong R&D and technological orientation are often classified to have a more cyclical ambidexterity in their organization (Kassotaki, 2022). These firms typically start with engaging in exploration where the aim is to gain new knowledge and later switching focus towards exploitation in which that knowledge is being developed and commercialized. This results in increased performance and innovative outcomes.

2.4.1.4 Reciprocal Ambidexterity

Reciprocal ambidexterity is one of the typologies that is shown to be least studied (Simsek et al., 2009). Reciprocal ambidexterity aims to describe how organizations balance between exploration and exploitation across time and units. Reciprocal Ambidexterity regards that different units in an organization actively take turns in focusing between exploration and exploitation (Kassotaki, 2022). The idea is that one unit starts with exploring new knowledge, while another unit takes that knowledge and applies them into real practice. The approach builds on that the second unit that applied the new ideas into practice can then report back to the first unit in order to support further exploration.

Reciprocal ambidexterity typically occurs in more complex environments in which the knowledge may either be considered too specialized or too broad for only one single unit to handle (Simsek et al., 2009). Furthermore reciprocal ambidexterity is often used in international collaboration or partnership due to that the organization may operate in a complex environment and therefore need to combine knowledge effectively (Kassotaki, 2022). Having a proper exploratory and exploitative knowledge sharing may lead to better relationship performance in that partnership. Simsek et al.(2009) highlighted that there is not much research regarding what full potential effects are with reciprocal ambidexterity but that some studies have indicated positive outcomes in terms of better relationship performance in those established long term relationships. Better relationship performance may regard that the partners may feel that the partnership is productive, fair and valuable.

In order for reciprocal ambidexterity to function, ongoing interaction with the units are seen as essential (Simsek et al., 2009). Continuous information sharing, transfer of resources and shared decision making are some important aspects that are essential in this interaction between the different units. The role of managers is seen as valuable in terms of ensuring that the information flows smoothly both within the organization but also between the partners.

2.5 Single-loop and Double-loop Learning

The concept of single-loop and double-loop learning, originally developed by Argyris and Schön, is considered as one of the most influential theories in organizational learning (Basten & Haamann, 2018; Auqui-Caceres & Furlan, 2023; Lipshitz, 2000). The theory was introduced as part of their broader work on organizational learning and human reasoning (Auqui-Caceres & Furlan, 2023), see Figure 2.4.

Summarizing the two contrary approaches of learning, they differ in the way errors are addressed and assumptions are questioned. In single-loop learning, individuals and organizations detect and correct errors without questioning the deeper assumptions, values or norms that guide their actions (Auqui-Caceres & Furlan, 2023; Basten & Haamann, 2018). The solutions are generally built on existing practices (Fiol & Lyles, 1985), resulting in single feedback loops, where solely current strategies and assumptions are utilized to develop quick solutions (Basten & Haamann,

2018). As further argued by Auqui-Caceres & Furlan (2023), single-loop learning with this nature tends to support short-term problem solving, resulting in enhanced operational effectiveness. However, the authors strongly emphasize that this type of learning, which does not produce deeper cognitive or behavioral change, has strong limitations in creating deeper learning and long-term change, which is needed for organizational growth.

In contrast to single-loop learning, double-loop learning refers to a deeper type of learning which is characterized by problem-solving in two feedback processes. In double-loop learning errors are not only corrected, instead they are also questioned further (Auqui-Caceres & Furlan, 2023; Basten & Haamann, 2018). Instead of merely adjusting actions based on existing strategies, double-loop learning involves examining the governing variables that shape those actions. When a mismatch occurs, the first step in the double-loop learning process is to reflect on the underlying assumptions, potentially modify them, and then adapt the new behavior accordingly (Auqui-Caceres & Furlan, 2023). By proceeding with this approach in problem-solving, double-loop learning can be understood as a higher level of learning, as it develops a deeper understanding of the root-causes and organizational wide assumptions (Fiol & Lyles, 1985). However, the literature highlights that double-loop learning can be challenging to achieve in practice, due to the risk of individuals relying on defensive routines that protect them from embarrassment or threat, which can inhibit open reflection, which is a key component of double-loop learning (Auqui-Caceres & Furlan, 2023).

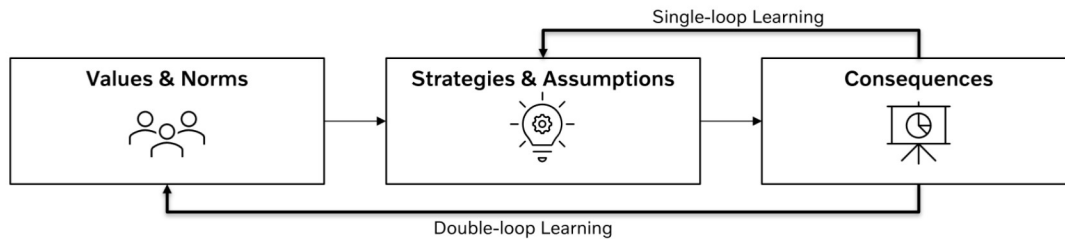


Figure 2.4: Single-loop versus double-loop learning pathways based on and adapted from Basten and Haamann (2018).

2.6 Theoretical Synthesis

Organizational learning is a complex and broad concept that has been addressed in research through multiple theories, models and frameworks. While several authors highlight the importance of interactions across multiple organizational levels and contexts (Crossan et al., 1999; Nonaka, 1994) they differ in their specific focus and contributions to understanding learning as a whole. Therefore relying on a single theoretical framework to describe organizational learning may risk a limited perspective. To address this, this study adopts a multi-framework approach to provide a more comprehensive view of organizational learning and its associated challenges.

As part of this study, four main theories or frameworks have been identified as central. The first is the 4I framework developed by Crossan et al. (1999) which explains organizational learning as a process that occurs across multiple levels through four interconnected processes. The framework focuses on how learning flows across these levels making it specially relevant for understanding how learning emerges, is developed and becomes embedded into organizational systems and routines. It also captures the dynamic mechanisms through which knowledge is continuously moving across levels in several flows. Given the aim of this study, which seeks to explore how organizational learning can be strengthened within technology development and implementation processes, the 4I framework is considered as central, as it directly addresses the dynamics of learning flows that are at the core of this research focus.

The second theory identified as important for the study is the concept of knowledge creation and transfer, mainly addressed through Nonaka's (1994) SECI model, explaining how different types of knowledge become important in learning processes. Connecting to the research aim of this study, in order to explore how knowledge flows in a company, it is crucial to also understand how knowledge is developed and made accessible across boundaries. Furthermore, the theory could also be important as an explanation to why specific knowledge may be difficult to transfer.

The third perspective introduced is the concepts of exploration and exploitation, which through its main contributor March (1991) addresses the challenges of balancing efficiency with innovative activities. Furthermore, different typologies of ambidexterity are presented as tools for working with this balance. This is particularly important to this study both as the tension is a general difficulty for organizations, as well as the context in which the study is done. In manufacturing companies the need for operation stability is crucial, which may influence to which extent organizations engage in exploratory activities.

The fourth, and final theory addressed is the concepts of single-loop and double-loop learning, which explains different ways of handling errors in organizational contexts (Auqui-Caceres & Furlan, 2023). For this study, it is important as it connects to the depth of learning, giving perspectives to if the organization is working with reflections on errors in a way that enables or hinders learning across the organization.

Together, these four theories or frameworks provide a complementary perspective on organizational learning that will help the study to address its aim. The combination of these theoretical perspectives form the analytical foundation of this study, presented below, which is used to structure the analysis of organizational learning within technology development and implementation processes at Volvo Group.

- Knowledge creation and transfer
- Learning flows across organizational levels
- Depth of learning
- Balancing Exploration and Exploitation

3

Methodology

The purpose of this section is to provide and explain the methodological framework of this study. The section provided an explanation to the research approach as well as the collection and analysis of the data obtained in the study.

3.1 Research Approach

This study adopts a qualitative approach to explore organizational learning and knowledge sharing within the manufacturing technology process at Volvo Trucks Technology and Industrial Division. According to Bryman and Bell (2011), the qualitative research approach is one of the most common types of research modes, which emphasizes understanding, interpretation and description of social processes within real life contexts. This approach is suitable for the study, as it enables an in-depth exploration of organizational practices, learning processes and challenges related to organizational knowledge sharing. Through a qualitative approach, the complexity of the organization could be captured.

Qualitative research further allows flexibility throughout the research process. As presented by Jemielniak and Ciesielska (2018), qualitative research allows the possibility of making adjustments to the research focus based on the objectives of the study throughout the research process. Rather than relying on predetermined assumptions guiding the results, the approach allows for exploration of new perspectives over time. This approach was particularly applicable for this study at Volvo since the understanding of organizational learning required continuous interpretation of new empirical insights from multiple organizational levels and functions. The qualitative approach chosen enabled the researchers to capture rich and contextualized data to relate to the aim of the study.

3.2 Literature Review

Engaging with existing literature is essential for the development of any academic study. The literature review therefore formed an important part of this study by developing a theoretical understanding to situate the empirical findings within existing research. The review also supported the interpretation of the findings as it enabled

the anchoring of possible improvements suggestions in existing research which allowed for more accurate and evidence-based recommendations, rather than relying on speculative ideas or personal judgment.

The literature review relied on peer-reviewed academic articles and books spruced through databases such as Chalmers University Library, Google Scholar and Direct Science. Key search terms included *organizational learning*, *knowledge sharing*, *cross-organizational learning*, *exploration and exploitation*, *organizational ambidexterity* and *organizational learning challenges*. The selected literature focused particularly on theories related to the creation and transfer of knowledge, learning flows across organizational levels, depth of learning and the balance between exploration and exploitation. The four categories provided the basis for the theoretical framework, but also the basis for the analysis of empirical findings.

3.3 Empirical Data Collection

As part of the practical and exploratory nature of this study, the collection of empirical data constitutes a central part of the methodology. To gain a comprehensive understanding of the developed knowledge sharing processes as well as the challenges in the area within the organization, data was gathered through complementary steps. The empirical data collection consisted of two main sources, which was internal organizational documentation and interviews with important organizational stakeholders. Combining multiple data sources contributed to a broader understanding of both formal organizational structures and enacted organizational practices.

3.3.1 Internal Volvo TTI Data Sources

To gain insights and understand how the manufacturing technology process was formally structured to facilitate knowledge sharing across the organizational functions, internal documentation from Volvo Trucks Technology and Industrial Division was reviewed. The reviewed material included process manuals and descriptions, internal process guidelines, project documentation, organizational presentations, and database structures related to manufacturing technology development and implementation. With consideration to confidentiality, the review was conducted to solely understand the intended organizational processes, structure and responsibilities, without examining or including any specific active projects or developments references in the documents.

The study was conducted on site which allowed the research process and findings to be influenced by the organizational environment. This helped the authors of this study to gain a broader understanding of how the day to day operations were carried out as well as highlighting the relevance and importance of the study's topic. Through continuous observations and interactions with internal stakeholders the authors gained deeper insights into the importance of strengthening organizational learning within the organization. Being present in the organizational landscape helped the authors to get quick access to clarifications to questions and thoughts

throughout the research process. Being on site with access to ongoing dialogue and immediate feedback contributed to a more comprehensive understanding of the studied processes and organizational context.

3.3.2 Interviews

Interviews were conducted as part of the study to support all three research questions, with a focus on both understanding the intended knowledge sharing structures, as well as the enacted practices within the organization. The study combined two types of interviews, where the initial focus was on unstructured interviews without a fixed list of questions to gain early insights, followed by more semi-structured interviews with themes and questions guiding the interviews to allow for comparison and structure in the research.

As discussed by Firmin (2008), the use of unstructured interviews could support the process of enabling the researcher to uncover insights structured questions might miss, and it can be a useful tool when studying new domains previously unknown or only partly known. This is also supported by Wengraf (2001), who argues that the focus of interviews should shift during the research cycle. In the early stages of building the research, a more unstructured or lightly structured approach is required, whereas in the later stages more heavily structured or fully structured interviews are required. Translating this into the focus of this study, beginning with unstructured interviews allowed for identification of key themes and processes, which then informed the design of semi-structured interviews. As argued by Bryman and Bell (2015), semi-structured interviews are the most common type of interview in qualitative studies, motivating the chosen method. Semi-structured interviews are characterized by the researcher developing a set interview guide with topics and questions to be asked, however, the method allows the researcher to shift and adapt the questions outside of the stated questions to further guide the interviewee on what to elaborate or focus on (Denscombe, 2014).

3.3.2.1 Selection of Interview Participants

The selection of interview participants were based on their involvement in the manufacturing technology process and their availability within the timeframe of the study. Given the size and the complexity of the organization, it was not possible to conduct interviews with all stakeholders related to the manufacturing technology process. Therefore, the empirical material represents insights from a purposely selected subset of important actors. An overview of interview participants is presented in Table 3.1

The study primarily reflects a global organizational perspective, as the research was initiated at the global level. This is also reflected in the interviewee selection scope, where a larger portion of interviews were conducted with stakeholders having global or cross site roles, and more specifically those involved in governance, coordination and the actual development of manufacturing technology processes. When referring to the global organizational perspective, this corresponds to individuals who have

a position such as director of manufacturing solution, manufacturing solution group managers, researchers, manufacturing technology manager (MTM), manufacturing technology specialist (MTS) and Center of Competence (CoC).

To complement the global perspective, also a few interviews were conducted with the local perspective. When referring to the local perspective, this corresponds to individuals having roles such as technical directors and local technical specialists (LTS). The scope included site insights from both Europe and South America. These interviews were included to capture how organizational structures are enacted and how initiatives are interpreted and implemented at site level. As many of the processes and frameworks developed at the global level are aiming to support local operations which is the core of the organization, excluding this perspective completely would have reduced the relevance of this study. At the same time it would not be feasible due to the complexity and size of the organization to cover a broader local perspective. Expanding the local context further within the timeframe of this study could also potentially reduce the depth and analytical focus of the research, as the focus was on high level improvements rather than directed smaller actions. The chosen interview participant selection on levels is therefore a way to balance the trade-off between ensuring contextual understanding and maintaining a manageable and meaningful scope for the study.

Table 3.1: Overview of interviewees and interview characteristics

N	Role (Level)	Interview Type	Procedure & Duration
1	Director of Manufacturing Solution (Global)	Unstructured + Semi-structured	On-site, 1 h
2	Manufacturing Solution Group Managers (Global)	Semi-structured	On-site + MS Teams, 1 h
4	Center of Competence (CoC) (Global)	Unstructured + Semi-structured	On-site + MS Teams, 45 min–1 h
1	Researcher (Global)	Unstructured	On-site, 1 h
6	Manufacturing Technology Manager (MTM) (Global)	Unstructured + Semi-structured	On-site + MS Teams, 1 h
1	Manufacturing Technology Specialist (MTS) (Global)	Unstructured + Semi-structured	On-site, 1 h
1	Local Technical Specialist (LTS) (Local)	Semi-structured	MS Teams, 45 min
4	Technical Director (Local)	Semi-structured	MS Teams, 45 min

3.4 Quality of Data

The quality of the data was analyzed through understanding the definitions of objectivity, reliability and validity, following the quality criteria outlined by Bryman and Bell (2015). These concepts were then used to evaluate the credibility and trustworthiness of the findings in this study.

3.4.1 Objectivity

According to Bryman and Bell (2015), it is important that researchers always aim to be objective in their studies. However, reaching a state where a study is completely unbiased is not possible regardless of how much effort the researcher put into it. The same situation can be understood differently by different individuals which may result in different interpretations and answers. Important to note is that the answers may all be correct to some extent depending on the context. Therefore, it is crucial to understand that biases could never be completely removed and it will to some extent lead to the objective of the study.

To ensure that the findings were unbiased in the study, the researchers focused on creating objectivity through different efforts in the research process. For example, researchers ensured that the interviewees that participated could freely express and explain their thoughts on the given questions. The researchers did not influence in any way the response which in turn resulted in that the data collected were only reflecting the perspectives of the interviewees. In addition, the researchers did not share information from earlier interviews with later participants, which ensured that each of the participant responses collected reflected on their own independent thought rather than risking it to be influenced by others. To strengthen objectivity further, interview participants were selected from different organizational functions and levels. This enabled the study to capture broader perspectives related to organizational learning.

However, a few limitations to objectivity should also be mentioned. Since the study primarily reflects a global organizational perspective, with fewer interviews with local representatives, there is a risk that some nuances or alternative interpretations of organizational learning are underrepresented. Furthermore, the interpretation of qualitative data is influenced by the researcher's own understanding and theoretical framing, especially in the analysis process where categorization and interpretation of patterns are needed. These factors imply, as Bryman and Bell (2015) emphasized, that even while steps have been taken to reduce bias, a complete neutrality cannot be ensured.

3.4.2 Reliability

Reliability could be described as to which extent the findings are repeatable over time (Bryman & Bell, 2015). It is closely linked with creating transparency where providing clear documentation is an important part. Providing high reliability allows other researchers to use the documentations, replicate procedures and obtain com-

parable results. To enable other researchers to achieve similar findings, the research process should be sufficiently clear and transparent, allowing other researchers to feel confident that the findings have not been manipulated.

In this study, the reliability could be considered high in terms of that the interviews generated relatively consistent and similar answers across interview participants even though they were from different organizational levels and functions. A total of 20 interviews with different roles and expertise were interviewed and many of them showed similar answers to the questions provided by the researchers of this study. This indicated that the data obtained from the interviews had a high reliability. Furthermore, the reliability of the literature study could be considered high as it was based on well known or established scholars within the field of research. The scholars chosen for the study are those that have either developed the theory themselves or have been cited in other well known articles regarding the subject of organizational learning. This supports the reliability as the usage of widely recognized and peer-reviewed academic sources increases the possibility that similar research approaches carried out by other researchers could lead to comparable findings.

3.4.3 Validity

Validity regards understanding how accurate but also how trustworthy the research method is for the study to capture what it aims to investigate (Bryman & Bell, 2015). There are many different aspects that can strengthen a study's validity.

To strengthen validity in this study, a few measures were taken. Before each interview, the purpose of the study was explained to the interviewee. This was done both to give an introduction to the topic, but also to ensure a shared understanding across respondents. Furthermore, all of the interviews were either conducted physical or online. No survey or email question was sent. Bryman and Bell (2015) explained that there is a risk for interviews misunderstanding the question through email due to the researcher not being able to explain it directly. Therefore the study chose to have interviews conducted physical or online to ensure that the questions were understood correctly which could lead to accurate data being gathered. A further measure to ensure that questions were not misunderstood was that all interview questions were adapted to the roles of the respondents to ensure relevance and clarity. For example if the interviewee had the role of a leader, then more leadership questions were brought up. Using this method also opened the possibilities of the interviewee answering the questions from their perspective and not just from a group or organizational perspective. Ensuring that the individuals understand the question in order to answer it in the most accurate way is considered essential. If the individual misunderstands the question may result in inaccurate results.

A further aspect to the validity of the study is the chosen method of unstructured and semi-structured interviews. By using the different interview types in different phases of the study, this supported validity by allowing the researchers to capture how respondents themselves framed issues related to organizational learning rather than creating predefined categories too early in the process.

In addition to these specific measures the study used triangulation as a general strategy to strengthen validity during the full research process. Triangulation refers to the use of multiple data sources and perspectives to cross-check and validate the findings (Bell et al., 2022). As indicated in previous sections, this study combined interview data and internal documentation with general insights and observation through participation in the organizational environment. This made it possible to compare and verify findings since patterns and themes across the different sources could be combined to a more robust and comprehensive understanding of the topic.

Although the findings of this study could be considered context specific and therefore not statistically generalized, they may still be transferable to some extent and be applicable to other organizational settings. The insights presented in this study provide learning aspects that may be relevant for similar organizations, particularly those operating in a global and cross-functional environment. The use of multiple data sources and the presence of recurring patterns across different functions globally spread indicate that these dynamics are not isolated to a single context and therefore may also be relevant in comparable organizational structures either within the larger organization or for external organization.

3.5 Data Analysis

The data analysis of this study followed an iterative process where empirical findings and theoretical frameworks were developed simultaneously. This allowed for the researchers of this study to continuously refine interpretations and review earlier findings when new insights were collected. This iterative approach was considered as relevant for this study since organizational learning is a complex research area which is often difficult to understand through isolated insights. Going back and forth between data collection and theory created the opportunity to build a more nuanced understanding of organizational learning within the manufacturing technology process. An overview of the iterative process leading up to the data analysis of the study can be found in Figure 3.1.

The empirical material was analyzed by using thematic analysis. As explained by McLeod (2024), this type of analysis could be explained as a qualitative method which focuses on identifying, analyzing and finding common patterns from different data sources. Thematic analysis is a highly applicable method that enables the researcher to understand people's opinions from the qualitative data by organizing and categorizing the findings. Since this study included a large amount of qualitative data, thematic analysis was considered as a relevant method for data analysis.

The researchers of this study discussed the findings continuously with each other. The aim of this approach was to compare interpretations and challenge the researchers assumptions. Through reflections on internal documents and interviews, the authors could identify recurring patterns, tensions and similarities across the empirical findings. Themes were then developed by grouping these findings together to address similar challenges, behaviors or knowledge sharing practices across the

organization. The identified themes were then also continuously compared and refined in relation to the theoretical framework to ensure analytical relevance. The theoretical concepts therefore functioned as both analytical lenses as well as support for structuring the overall findings.

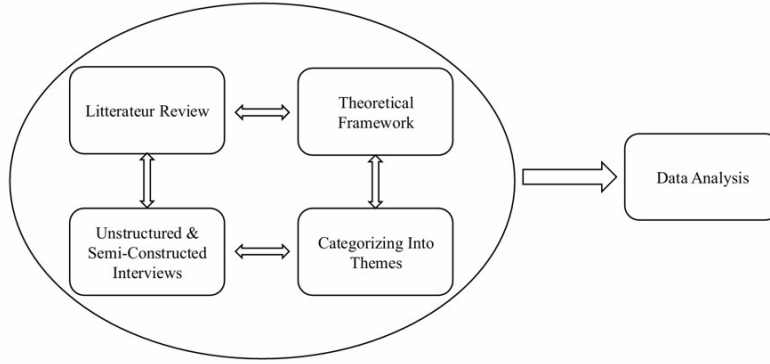


Figure 3.1: Overview of the iterative process.

3.6 Ethics

To ensure ethical responsibility in this study, all interview answers were presented anonymously. The researchers achieved anonymity by excluding stating which specific roles had provided the answers. Before officially starting the interview, the researcher first clearly explained what the purpose of the study was and how the interviewee's answer was supposed to be used in the research. Furthermore, the researchers informed the interviewee how their anonymity would be presented and that their response would not directly be traceable to them in the results.

Considering ethical responsibility from the organization perspective this was also seen as important, as the researchers had access to organizational processes and internal documents. The researchers of the study continuously discussed whether the information obtained was seen appropriate to include in the findings. To fully ensure confidentiality, the process was done in collaboration with the case company's supervisor, who reviewed the material and approved if it could be included in the findings.

4

Empirical Data

This section aims to present the data collected for this study. The data is collected through interviews with key stakeholders, internal documentation and observations from the organizational environment. The section provides an overview of the data relevant for further analysis in later sections.

4.1 Trucks Technology & Industrial Division

Within Volvo Group, a department referred to as Trucks Technology & Industrial Division (TTI) has the overall responsibility for all production of the Volvo, Renault and Mack Trucks but also the engines, transmission and spare parts that are provided to Volvo Group's truck customers, see Figure 4.1 for position in the full Volvo Group organizational chart. Trucks Technology and Industrial division consist of five value chain functions including end-to-end responsibility for sourcing, development, and production. The value chain functions cover the full scope of powertrain solutions, development of software, final assembly, and service market solutions. The five value chain functions are: Powertrain Technology & Industrial, Function & Software Defined Vehicles, Cab Over Trucks, Conventional Trucks, and Service Operations & Technology, see Figure 4.2.

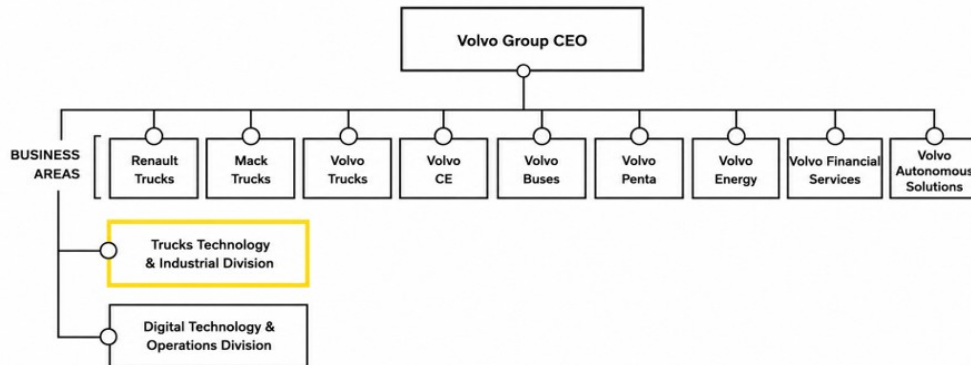


Figure 4.1: Overview of the organizational structure of Volvo Group, narrowing from the broader organization to the specific division within the scope of this study.

This study is conducted from the perspective of Cab Over Trucks. However, it is essential to emphasize that all value chain functions are interdependent, continuously influencing and reinforcing one another. As such, learning and development within the Cab Over Trucks domain cannot be fully understood in isolation. Instead, improvements and knowledge in this area are dependent on and contributing to the broader value chain. Efforts to increase learning and development in this value chain function require coordination and cooperation with other value chain functions, as their input is important for the overall TTI system performance. The Cab Over Trucks value chain function has a high degree of complexity, as the function spans multiple truck brands and models. It relies on input from other functions for enabling the production processes to operate in alignment with the software, service, and system requirements. Furthermore, the connection to input value chain functions is of importance as these produce components used in the final assembly.

As part of the full system, Cab Over Trucks is also related to the four global functions: Truck Technology, Truck Quality, Purchasing, and Logistics. The global functions aim to ensure that all five value functions are strategically united and competitive according to overall TTI strategic decisions for competitiveness and development. Furthermore, there are five support functions that do not directly contribute to manufacturing or physical production of the products but are crucial for enabling core activities to operate efficiently. The five support functions are Business Control, People & Culture, Digital Operations, Communications and Legal & Volvo Group IP.

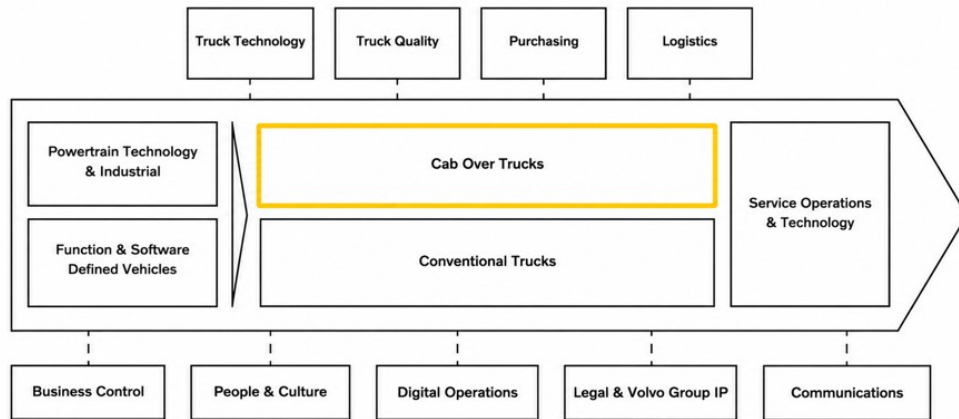


Figure 4.2: Overview of the value chain functions, global functions and support functions within the scope of Trucks Technology and Industrial Division.

4.1.1 Coordination at TTI

At TTI, a central focus is to identify new products and production technologies that support the overall strategy and long-term target vision. Within the domain of Cab Over Trucks, this work is organizationally structured around five distinct compe-

tence areas, each representing a specialized field of expertise. Each competence area aims to drive world-leading manufacturing technology development, while concentrating on different aspects of the overall solutions. The five competence areas are: Body in Color, Final Assembly and Cab Trim, Powertrain, Internal Logistics, and Embedded Software. As shown in Figure 4.3, each competence area is led by a designated leader responsible for setting direction, overseeing operational performance, and fostering professional development within their domain, except for Final Assembly and Cab Trim and Body in Color, which share a common leadership under Vehicle, or also referred to as Manufacturing Solutions. Important to note, is that the different competence areas also belong to different organizations within TTI, putting a certain complexity to the overall structure.

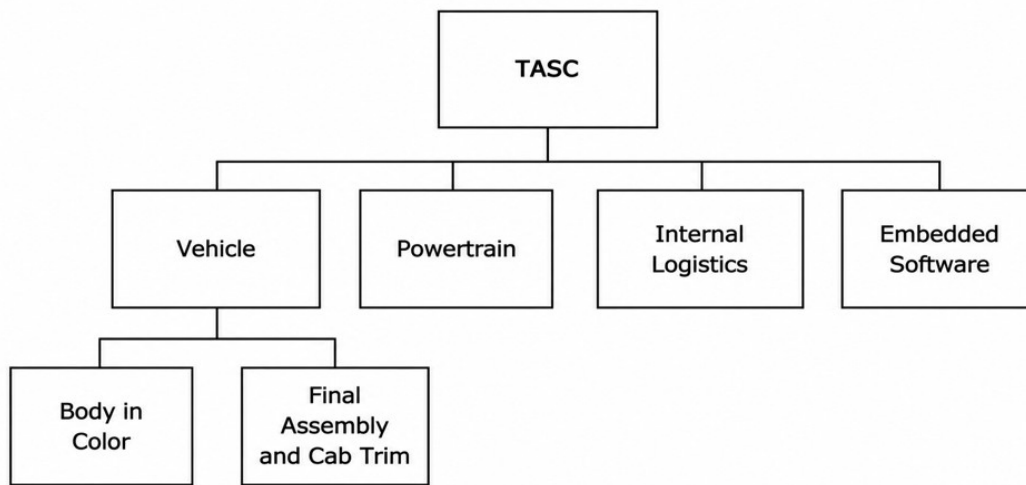


Figure 4.3: Organizational structure for the different competences areas within the scope of Trucks Technology and Industrial Division.

To ensure collaboration and knowledge sharing across the competence areas, the four competence area leaders participate in a forum referred to as TASC. This forum serves as an integrative and strategic platform in which cross functional priorities, decision and synergies between competence areas are being discussed and developed. This structure ensures that each competence area maintains its own autonomy while remaining interconnected through shared leadership and collective governance.

Within this forum, the actual development activities are being carried out in the individual competence areas, where the domain technical capabilities and expertise reside. Each competence area therefore plays a distinct role in advancing manufacturing technologies within its field. Due to the different nature of operations, each competence area spans different areas of the TTI scope.

The Manufacturing Solutions function is responsible for developing and continuously improving the methods, systems, and technologies used in the manufacturing process

of trucks. The function serves as a critical link between process technology and production, ensuring that products can be manufactured efficiently, consistently, and cost effectively across all sites globally. Manufacturing Solutions is responsible for the vehicle value chain (Final Assembly and Cab Trim and Body in Color) and the processes that both directly and indirectly affect the production process in this field. For the competence areas, Body in Color is responsible for the processes where the vehicles' metal components are assembled and welded together into the structural frame, and painted, ready for assembly. Final Assembly and Cab Trim is responsible for the final assembly (turning the parts into a functional truck) as well as the cab trim where the interior is finished.

Powertrain shares many of the responsibilities with the manufacturing solution function, but the scope is instead limited to the engines, transmissions, axels, and ESS of the trucks. One key aspect that is significant for Powertrain's development is the high investment costs related to its operations, leading to a complex process in terms of implementation of new technologies.

The Internal Logistics competence area is responsible for the development and optimization of material flow solutions that support the manufacturing process. Within the scope of manufacturing technology development, the competence area designs and validates logistics concepts, including material handling systems, warehouse automation, line feeding systems solutions, and internal transport systems. The function ensures that logistics systems are technically integrated with production processes, scalable for industrial settings, and that the solutions are aligned and can be integrated into the system requirements. The competence area is by its nature built to act cross-functionally for both Powertrain, Body in Color and Final Assembly and Cab Trim , adding to the size and complexity of the function.

The embedded software competence area is also working cross-functionally with the focus of driving the development of software technologies critical to advanced manufacturing systems. This competence area aims to ensure that software development is coordinated with manufacturing development, which in turn enables integration and scalability.

While all of the five competence areas work and contribute to manufacturing technology development, each operates with different processes, methods, and expertise. Each area does not only focus on manufacturing technology development, but also works structured internally to manage activities efficiently, coordinate resources and ensure technical excellence. While the specific structures vary based on the nature of the function, all areas combine leadership, specialized teams, and responsibilities to drive technology development from concept to industrialization.

Going deeper into the TTI organization, it is found to operate in a decentralized way where decision making, and operational responsibilities and ownership are distributed across multiple functions. The decentralized structure provides autonomy to the local factories which can manage its own process, allowing for efficient responsiveness and implementation of solutions to the specific local requirements.

The structure enables rapid problem solving and flexibility rather than forcing uniform solutions across all sites. However, while decentralized structure can ensure efficiency, the high complexity in the networks which include different production processes, various technologies and sites spread across the works, are therefore in need of mechanisms for coordination. This required mechanism for coordination aims to ensure that the structure does not fall into fragmentation. To ensure that local autonomy does not lead to fragmentation, this global formal structure has been established to support organizational collaboration and knowledge sharing for the purpose of economies of scale.

4.2 The Organizational Setup

For all competence areas directly related to the manufacturing of finished products or components included in the final trucks, the same internal organizational setup is applied. This structure, known as the MTM network, is used to ensure alignment across sites and that the strategic direction is followed across the network.

Giving background to the structure, coordinating the networks related to all the competence areas presented above is a complex and challenging task. With factories geographically widespread, and with different factories focusing on different aspects of the production there are some common challenges directly occurring if there are no structures available:

- The same product but x amounts of assembly lines
- Not learn from each other
- Will repeat the same problem
- The same quality issues
- All factories need to investigate the same technology
- Very costly and inefficient

To solve these inefficiencies, actions of creating a structure for working across these boundaries had to be created, which was done through the MTM network with the goal of being “*one team supporting each other to secure one common manufacturing platform*”. This network structure has been developed gradually from 2012 and has been in effective use since approximately 2015 across functions, and is intended to cover both the local and the global levels, thereby connecting all parts of technology development in the organization. This includes everything from early investigations and strategy development to creation of specifications, working with implementations, as well as continuous improvement efforts.

4.2.1 Formal Roles in The MTM Network

To support the intended “one team” approach, the MTM network relies on formal roles that are created to enable effective coordination across sites and organizational levels. In relation to the topic of this study, namely organizational learning in technology development and implementation, four roles were identified as particularly important for connecting local operational teams and global development teams together. In addition to these, there are also additional roles existing, however they were not highlighted to the same extent in the interviews in relation to the focus of this study.

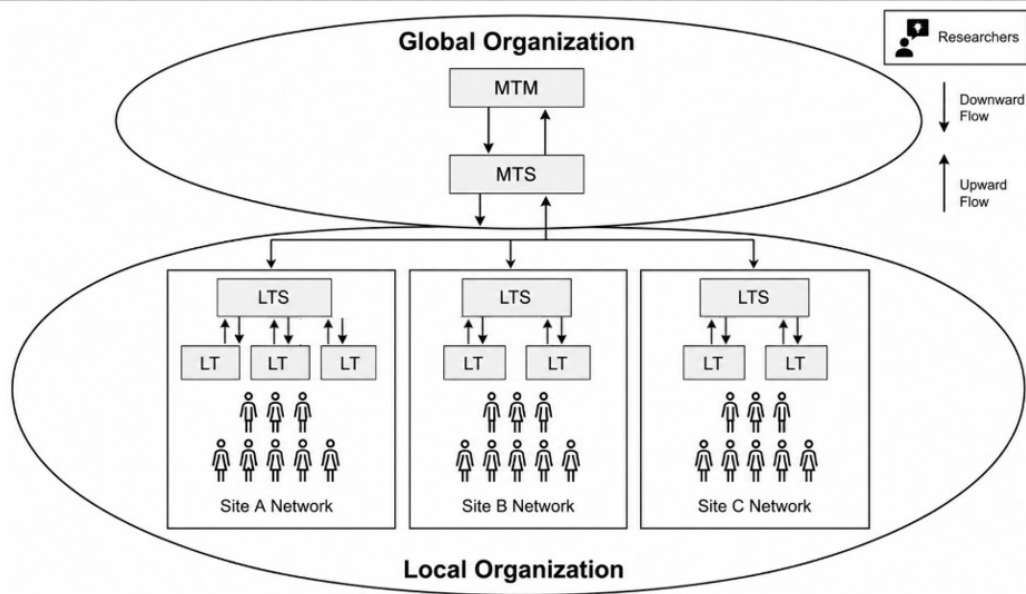


Figure 4.4: The MTM network.

As visualized in Figure 4.4, there are three roles with direct connections to support both the upwards and downwards flow of information between local and global teams. The first of these roles is the Manufacturing Technology Manager (MTM). The MTM is working on a global level, close to the responsible manager for the competence area, however the role does not include any formal governance to dictate decisions on a local level. Furthermore, the MTM is responsible for setting a vision and strategy within their area, as well as having the responsibility to develop a technology roadmap and ensure that best practice is defined in the used master process. Active information sharing regarding if new insights have been initiated from the sites with the Manufacturing Technology Specialist (MTS) is a key coordination task included in the role.

Compared to the MTM, the MTS is more closely linked to the local level, but still has a global responsibility. The MTS is responsible for contributing with input and proposals to innovation initiatives, technology roadmaps and to define best practice globally. With their strong technical knowledge in a specific field, they are also

responsible for providing technical support to plants, especially during the first implementation of new technology. Related to this, the MTS is also required to develop, document, and maintain master processes and standardization, as well as supporting other roles in defining prerequisites from operations in product development. One key aspect of the work is to manage a network with local technical specialists (LTS) and coordinate continuous improvement and indicate training needs to these networks.

The LTS is placed in the intersection between the local and global perspective, reporting directly to the MTS as well as the local site network. The LTS is geographically located and employed at a specific site. This role includes highly specialized technical knowledge within a specific area of operations and should aim to identify and communicate the needs of this area. The LTS is responsible for highlighting problem areas, as well as identifying possible aspects for future development within manufacturing technology. The LTS works closely with other local technicians, allowing for direct and accurate input from the local site which the LTS is representing.

In addition to these more technical specialist roles, the MTM network is also supported by researchers that are responsible for building knowledge and competence to improve production performance. This work includes cooperation both within and outside the company, e.g. through university research or with other companies. The work is initiated and executed in different projects within a specific area up to MRL6, and is related to conducting studies, publishing research papers, and engaging in conferences to strengthen the development in new areas. Furthermore, the researchers also support and work with the MTM network in technology development projects, as well as helping with identification of competence needs for future adoption of technology. A key role for the researchers is to act as enablers, securing the transfer of projects from the research phase to production development to gain advantages of new technologies.

4.2.2 Information Sharing Practices

While formal roles and responsibilities define the structural framework of the network, coordination across functions and production sites is supported by a range of established organizational practices. These include meeting structures, roadmap processes, master processes and related information sharing practices, which provide important forums and procedures for aligning activities. These practices form an important foundation for collaboration and knowledge sharing within the organization.

4.2.2.1 Master Processes

One of the most central mechanisms for supporting knowledge sharing and learning within the organization, is the ability to structure and document important activities. Master process enables this by providing a standardized framework for how work is performed and documented, making knowledge accessible and transferable

across the organization. A master process for manufacturing technology is a standardized documented way of performing a specific task that defines best practices, sequences, and controls. It is needed to ensure consistency, quality, safety, and efficiency across production sites. A master process defines the critical steps of each process and is the model to be used in all implementations. Master processes are established for all activities in manufacturing, assembly, and logistics based on best practices known.

The level of detail in the master process varies for different aspects of production. In a situation regarding safety related or complex processes built on many years of experience, the master process can be heavily detailed all the way down to the exact equipment to be used. In other cases, the definition is on a high level, without too much focus on details, giving more freedom to each plant. This level of detail is categorized as ABC, where level A describes the process steps in sequence, level B describes the operations within a process in sequence, and level C describes the method, equipment or tools required per operation. As indicated in interviews, it is very important to understand the way of working with master processes when discussing learning and knowledge sharing. The system is built to take into consideration that each plant is unique in for example its product mix and line speed, which is the reason for not specifying detailed workplace layouts or level C processes for all operations. Due to differences in variability, volume variation, and flexibility, utilizing a centralized model as the competitors is not suitable. It would be too economically inefficient to rebuild every factory in order to implement a one single standardized solution across all sites. Furthermore, having large-scale production solutions for low-volume production would not be applicable and also result in waste of capacity.

In addition to the level ABC master processes, the concept of global/adaptable/free is important to highlight as part of the internal way of working. This concept can be seen as a decision of flexibility, which for the master processes describes whether a choice of solution is constrained or not. It ranges from fully mandatory solutions to a selection of approved alternatives, to complete freedom of choice. As defined by the company globally the definitions are accordingly:

- Global - There is ONE decided/specified solution identified as best practice based on SQDCEP or other requirements
- Adaptable - There are MORE than one decided/specified solution that can be selected depending on product, capacity, investment level etc.
- Free - There are NO decided/specified solution(s). Not prioritized/ documented

The master processes are created scalable to fit high/low volume production and different product requirements for value/high end products. One key aspect of the master processes is that these are constantly undergoing continuous improvement to ensure that best practices are up to date. Through the master processes, key

industrial concepts are shared, which reduces the total cost of implementation at several sites, since using the same solutions means one development and re-usage of knowledge. It also enables use of manufacturing engineering resources across sites, as well as giving purchasing leverage to negotiate better equipment prices and suppliers to develop customized solutions to the company.

Master processes are related to short-term development, spanning the time horizon of today +1 year. These continuous improvement activities are naturally linked to exploitation activities such as applying and standardizing current knowledge, optimizing existing operations and workflows, and meeting immediate business needs.

4.2.2.2 Manufacturing Technology Roadmap

Another highly important practice that aims to support technology development and learning within the organization is the Manufacturing Technology Roadmap (MTRM). The MTRM includes larger research projects and development needs for strategic competitiveness, aiming at identifying potential new products and/or production technologies to support the overall strategy and target image in the long-term perspective, spanning the time horizon of 5-10 years.

The MTRM process is divided into yearly cycles and brings together several stakeholders with importance for competence development across the full organizational scope. As detailedly introduced in internal documentation, the process can be found to be quarterly sectioned, with different focus areas over time to support development:

- **Q1** – The aim of the first quarterly section is to capture and share inputs across different sites and teams. Within this work, each MTM area is responsible for gathering requests that may be of high interest to future technology developments. Other stakeholders, e.g. researchers, are also able to add needs to the process. After initial screening of inputs to the MTRM database, selected projects with potential for further development are filled into a list of potential TD projects. This phase also constitutes identifying gaps not covered in existing MTM networks and target settings based on mapped needs.
- **Q2** – The second phase is all about further clearing the projects by identifying actions to fulfill targets, and anchor but also decide the roadmap of the year. For all projects going further in this work, clear activity descriptions including budget should be available.
- **Q3** – Going into the third phase, it is all about prioritizing and anchoring budgets per MTM area. Activities should be consolidated for higher project efficiency across organizations and areas.
- **Q4** – The final phase of the year consists of final budget approval and resource planning within the project teams. At this stage, the project is all set to start development and the final part is to review the roadmap and kick off next year's activities.

The yearly roadmap process could be seen as the initiative to support sites in recognizing development needs and creating opportunities for this kind of development. However, the actual process of conducting research projects moves further to specialized project teams. For projects with approval, these go further to the actual technology process, see Figure 4.5.

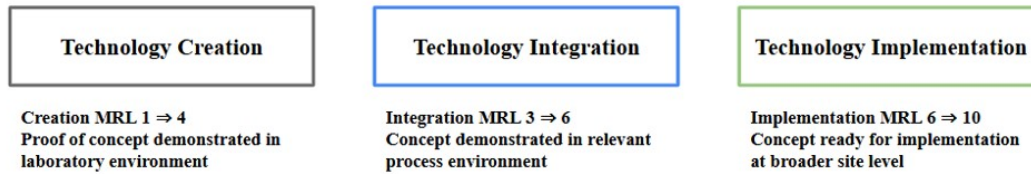


Figure 4.5: The technology development process.

In the technology development process, there are three phases which have a predetermined MRL maturity level. The MRL maturity level aims to describe how well mature the project development is with a scale of 1-10, where 1 indicates a lower maturity and 10 a higher maturity. The first phase for a project in the process is to go through the technology creation phase. The technology creation phase consists of gathering, analyzing, and collaborating with academia to get a fundamental understanding and knowledge that concerns the research project. The MRL maturity in technology creation tends to be on a scale of 1-4 which indicates early pre-production phase where work is mostly theoretical and is aimed towards learning, proving feasibility and reducing unknowns.

The second phase in the MTRM process is the technology integration phase where the purpose lies in turning research data into more applicable formats and incorporating it into the process. This may be accomplished with a pilot plant, where the aim is to evaluate and test new ideas before implementing into a full scale production process. Furthermore, the integration phase aims to construct a master process that other factories may use. Notably in some cases, a master process may be constructed for future purposes if it is found to be not applicable at the current stage for the organization at the given time. The maturity level in the technology integration phase tends to have a scale spanning from 3-6, which indicates that technology is subject to further development and research regarding its applicability in real world implementations.

The final phase is technology implementation, where each factory may be obliged or choose to implement the new technology, depending on how the master process has been constructed. The technology implementation phase is considered a site project, in which each plant is responsible for financing the technology development independently. The maturity level in the technology implementation phase has a scale between 7-10, which indicates a more mature process that may be used in full scale production.

4.2.2.3 Network meetings

The network meetings aim to ensure continuous learning and knowledge sharing across the organization. Based on the master process, defined roles and the MTRM, the meetings aim to provide structured forums where stakeholders can discuss challenges, exchange experience and align improvements. Within the role structure, network meetings support collaboration and ensure that knowledge generated in the network is shared and available to apply across the broader manufacturing network.

As part of this work, there are formal process bluesheets available for MTM/MTS and MTS/LTS network meetings. The bluesheets highlight important aspects of what the meetings should include to fill its purpose. For example, the participants, the frequency and format, the purpose, the mission, performance indicators, and agenda are included. Different bluesheets have been identified as active within different MTM areas, however they are all structured in a way to fulfil the purpose.

4.2.2.4 Center of Competence

Center of Competence (CoC) is one of the later introduced mechanisms to ensure effective transferring of knowledge across the whole organization. The concept was introduced to the organization around 2020 to highlight and build up a stronger foundation for aligning, sharing, and securing knowledge transfer. Furthermore, the aim is to identify and secure potential synergies within defined areas, as well as identify potential education needs. The CoC is created based on a relatively loose structure with the expectation of being a point of contact both internally and externally for the subject or technology area of which the CoC regards. The ways of working are built on voluntary participation with no formal meetings structure introduced, leaving freedom to how often meetings should occur.

As defined in the documentation regarding the formation of CoCs, each CoC needs a leader with time dedicated to the task. Reviewing the information regarding deliverables, the work should define and own a cross-functional roadmap covering the defined area including aspects such as new technologies, ongoing initiatives, needs within manufacturing/production evolution and keep status updates on the TASC forum.

The work with CoC should be continuous and the active CoCs might change over time depending on the technology development. Internal documentation shows that there are currently seven CoCs that have been identified as either active or status unclear.

4.3 Actual Practices

This section aims to describe the actual practices, highlighting both formal and informal practices as well as other important pathways that shape how learning and technology implementation take place in everyday operations. This section aims to enable an understanding of how the intended structures are applied in practice

and helps identify alternative pathways that may complement the structure that the company might need to take into consideration for designing systems that allow for efficient sharing of knowledge.

4.3.1 Center of Competence

Having described the baseline for the Center of Competences, this section presents how these forums are currently organized across different parts of the organization. The purpose of this is to provide an overview of how the CoC are structured, governed, and operated in practice to be able to compare against the desired outcomes or wishes of the forum.

According to the interviews with several of the persons highlighted as leaders of CoCs, not all are organized and operated in the same way. In total, 4 out of 7 CoCs were selected to represent the interview scope of this part of the study. Table 4.1 presents an overview of the four CoCs examined in this study, comparing their structure and governance, activity level, technology maturity, purposes and also characteristics and challenges highlighted in interviews. The comparison shows differences in how they are operated, where some have developed towards formalized structures with strong governance, where others remain more loosely structured.

Table 4.1: Overview of CoC domains and their characteristics

Category	Vision System	Flow Visibility	Intelligent Automation	Additive Manufacturing
Structure & Governance	Formalized network with chairman and structured meetings	Light, voluntary participation with informal structure	Small group (5–10 members) with defined agenda	Weak, informal structure
Activity Level	High (biweekly meetings)	Medium-low (sporadic meetings)	Medium (biweekly meetings)	Low (no regular meetings)
Technology Maturity	High	High	Low/Medium	Low (no in-house implementation)
Purpose in Practice	Coordination of vision solutions and business value realization	Knowledge sharing and tracking solution mapping	Early exploration and technology sense-making	Informal knowledge exchange and networking across functions
Key Characteristics / Challenges	Centralizing coordination and faster decision-making; governance recently strengthened	Limited formal authority; acts mainly as information hub	Focus on exploration and learning rather than industrialization	Low visibility; relies on informal contacts and email communication

4.3.1.1 Vision System

The Center of Competence for Vision System was initially developed as a support structure to handle and guide requests across the organization related to development and implementation of the internal Volvo Vision System. The CoC was providing examples and reference materials through a SharePoint, in which different functions could gather and understand the internally developed system related to their needs. As the demand grew across the organization, it became clear that a higher level of coordination and communication was necessary to provide the support needed across the organization, leading to the creation of a new “global CoC network”.

In December 2025, the CoC for Vision System was re-constructed towards a more formal version, with meetings held every two weeks with a designated chairman and contributors from different parts of the business owner network. In this formal forum “*Computer Vision Business Value Realization Network Meeting*” the mission is to turn business opportunities into products, solutions and initiatives with a clear vision, strategy, goals and budget. The network should work with both existing capabilities and appointed applications, as well as work with defining future Vision System capability needs. Furthermore, the new structure is also designed to not only cover the Volvo Vision System, instead also integrating all existing knowledge related to Vision Systems in the organization. The CoC is intended to serve as a central base for storing and structuring knowledge, with the long-term goal of expanding beyond just having a platform for documentation towards a more solution-oriented support. The ambition is to move toward a “one problem – one solution” approach. From the interviewee’s perspective, the most important improvement lies in faster decision making, and by bringing the decision makers together in the same forum quicker alignment on actions can be achieved.

The previous work with Vision Systems and collaboration related to it was largely limited to the competence area where the person is working within, and coordination across different functions was difficult. A major goal of this new CoC is to provide a clear and fast entry point for starting vision-related processes, so that there is one single place where sites can turn for guidance and support, without fragmentation across competence areas. To achieve this, the technical development organization must have the right competence and the right people involved. Global roles play a key part in maintaining communication within formal networks, but the structure also needs to connect effectively to local sites.

4.3.1.2 Flow Visibility

The Center of Competence for Flow Visibility focuses on understanding the current state of tracking solutions available on the market. Much of the work done in the CoC is about coordination of both internally available solutions, as well as possible solutions on the market, with the goal of reducing the amount of separate solutions for similar user cases. To support this an implementation flow chart including details about different solutions and user cases has been created to visualise and guide

implementation actions. Access to this CoC is granted for people in the organization interested in tracking, and most often these participants are stakeholders that are driving tracking initiatives somewhere in the organization. Previously, the meetings were held once per month but today they occur more sporadically. The participation is voluntary and the structure is international light where the primary purpose is to share knowledge rather than any form of enforcement. However, some of the discussions previously taking place in the monthly meetings, may have been redirected into a new formal organizational structure that has been developed recently to support the work of standardizing logistics solutions overall.

A recurring problem within the area is local sub-optimization. The interviewee explains that local sites are often contacted by local suppliers who present solutions that may have a valid business case for a specific site but are expensive and poorly aligned with global needs. These initiatives then stay and exist in silos, decoupled from global solutions and the support associated with these. For the CoC, the low visibility of tracking activities is seen as a significant challenge, and the motivation for sharing information such as articles, presentation, and supplier information is primarily to build an initial understanding of what exists and where. The CoC aims to create a broad picture of ongoing activities in the technology domain, even if it cannot directly govern them. While the CoC was initially visioned to own a roadmap, in practice it lacks formal authority to do so. Instead, it serves more as a mechanism to filter, compare, and sometimes discourage local initiatives by highlighting existing solutions. All together, the interviewee sees the CoC as primarily serving as a resource hub containing articles, documentation, and shared materials. The knowledge is currently stored in a SharePoint, though the interviewee suggests that a more discussion-oriented platform such as Viva Engage could also be suitable.

For the future development of the CoC, the interviewee sees potential in clarifying the relation between formal forums and the CoC, and how these should further support each other. Another interesting aspect mentioned by the interviewee is the consideration of the technology maturity, where different solutions may need different support. For example, once solutions are operational, users still need a forum for discussion and problem solving. If this should be a task for the CoC or perhaps additional informal forums remain to investigate.

4.3.1.3 Intelligent Automation

The Center of Competence for Intelligent Automation aims, according to the interviewee, to extract and scale what truly creates value for industry from a long-term perspective. The CoC is established with a deliberately humble approach, focusing primarily on encouraging dialogue and getting people to discuss new technology, shared challenges and opportunities. The technology domain of intelligent automation is relatively immature, and there is no established core competence within the area. Therefore, much of the role of the CoC is to support early stage exploration, learning, and sense-making rather than industrialization. For this type of development, the interviewee highlights the importance of creating an open, inviting and welcoming environment where one cannot be overly restrictive or dismissive

as openness and curiosity is essential for building engagement. The interviewee also highlights that there is a shift visible in the company today, where many of the CoC forums take a turn towards industrialization teams, which operate more as decision making forums. This is not the direction which the interviewee finds that the CoCs should go, instead it may be that when technologies move toward implementation and execution, other structures or forums may become more relevant than the CoCs.

This CoC in particular is organized through biweekly meetings, with around five to ten active participants. There is a meeting agenda which is followed, including status updates, discussion on partners and suppliers, tool updates, review of action logs, and open discussion points where both the leader of the CoC and the members can bring new proposals, project ideas, studies and also information about relevant events connected to the topic.

To raise awareness of the technology development conducted in the CoC and to increase the visibility further within the organization, work done is shared through presentations in various forums outside of the normal meetings, e.g. in annual kickoffs, site dialogues, internal communication channels, and videos. The wish from this CoC is that when the point is reached where a decision needs to be made to move towards rollout, the CoC should leave but ideally some representative should be part of the project (either as project manager or supportive role) to ensure that existing knowledge is used. The CoC should then further focus on early stage development again, leaving the coordination and implementation to other forums. One important part highlighted is also that projects that do not result in implementation are still considered valuable. Failed or canceled projects can also be successful in terms of learning, as they can help identify paths that should not be further pursued.

4.3.1.4 Additive Manufacturing

The Center of Competence for Additive Manufacturing according to the interviewee is perceived to have a relatively low visibility and attention within the organization. Despite the launch a few years ago it has not sustained or had a strong presence in daily work. Furthermore, the CoC showed that it does not have any recurring meetings or a formal structure. Instead, work has mainly been driven through informal contact ways, such as sending emails to the stakeholders that are active in the question discussed. The interviewee explains that often those who are already engaged tend to stay active, while less active stakeholders are harder to reach, which could also imply that some individuals or groups may be missed entirely. The main participants are global functions, and questions that reach the CoC from manufacturing sites rarely come from coordinated, strategic needs, rather from individual engineers with a personal interest. Since additive manufacturing is not yet fully implemented in-house, sites often lack dedicated resources and time, which lead to sporadic engagement. It is highlighted that factories tend to focus on projects that are already underway, and the fact that additive manufacturing development requires engagement in projects that have not yet started leads to that it can be hard to include the sites early on. The work of integrating additive manufacturing solutions into future programs must begin early in the development, but this is hin-

dered by a lack of stakeholders with the right early input. Consequently, additive manufacturing activities often emerge as exploratory or interest based efforts.

One challenge mentioned is the balance between presenting the idea on the agenda and the coordinated planning of it. Although the CoCs could support this coordination and ownership of ideas, the more established MTM networks are preferred for this type of work, as they provide clearer accountability and are more frequently used. With the current setup for the CoC, it relies on shared responsibility and less structured knowledge dissemination. However, the MTM network also sometimes struggles with early technology development, as it requires well-functioning internal communication between roles and departments. A major challenge for new or early technology is to find and involve the right departments and stakeholders early enough, as it needs to be coordinated with e.g. product development. For the MTM network to identify equivalent “technology exploring roles” in product development or other central functions becomes crucial but is relatively hard to realize due to the high complexity of the full company network.

Comparing the MTM network with what benefits the CoC has brought to the technology domain, the interviewee emphasizes the benefits of increasing visibility of competence across functions. Through the CoC, the interviewee has gained access to many new contacts working with additive manufacturing outside the closest network. However, these individuals are often organizationally very distant, making day-to-day collaboration difficult. Information forums in general (such as CoC, or other contact ways) are seen as having clear strengths as they enable freer information sharing, compared to formal forums which sometimes can restrict knowledge flow due to structure and hierarchy. The main formal forum for knowledge sharing across functions is the TASC. However, this forum is mentioned to have a focus on more management related topics and less suited for detailed technical discussions, risking that projects progress far before relevant stakeholders becoming aware of them. The alignment across functions is mentioned as important in the deliverables of the CoCs, as one intended goal for the forum is to create a shared roadmap. However, this is described as difficult in practice since each unit must fund its own projects, requiring separate budgeting and prioritizing.

4.3.2 General Insights from the Global Perspective

During the interviews, several aspects of technology implementation were discussed. In many cases, the intended structures are highlighted as the way of working, however there seems to be some situations where the actual way of working differs or is not fully realized by the organizational structures. In this study, global representatives refer to individuals having the role of a director of manufacturing solution, manufacturing solution group managers, MTM, MTS and researchers.

4.3.2.1 Transition from Technology Integration to Implementation

One of the first insights highlighted by the interviews was that, in some cases, there would be no recipient from the factory level that would take the full responsibil-

ity of implementing the technology that was developed by the global team. This seemed to mostly occur when transitioning from the technology integration phase to the technology implementation phase. Furthermore, the interviews mention that expensive investments may be one of the reasons why plants may not choose directly to implement a global solution. The interviews continued to emphasize that in the technology implementation phase the factories are financially responsible for carrying out the implementation by themselves. Insufficient knowledge regarding what potential the technology may deliver to the plants was another point that was brought up in the interviews.

4.3.2.2 Time and Competence

Another central theme across interviews with the global representatives is the focus on time allocation and competence distribution across the networks. Comparing different networks which are guided to be created according to the formal role descriptions, there are differences in both how the roles are allocated, as well as how much time that is dedicated for the work. There are also situations where roles are not allocated at all, leaving blind spots or gaps in the network.

Regarding the time perspective, this was a factor highlighted at both the MTS and LTS levels, where several of the interviewees described that there is a perception that not sufficient time is allocated to the role. This was discussed in relation to the level of learning as a factor that may influence and impact the overall learning performance. For example, interviewees highlighted that many of the resources with strong links to the local sites tend to be occupied with the daily operations and short-term problem solving, rather than putting time and effort into the long-term development, which is also part of the formal role description. Furthermore, it was described that this may sometimes also lead to situations where roles extend beyond their intended boundaries, for example there are scenarios where an MTS steps in to provide additional support to the LTS due to limited time. According to the interviews, this may influence how resources are distributed within the network, with short-term operational needs tending to receive more focus compared to broader cross-site development and learning activities.

The other aspect, regarding competence, was discussed from several perspectives. One part highlighted in the interviews was the ability to keep competence at a good level related to new technologies. For example, in some situations, local sites were described as having limited knowledge regarding technology solutions brought up by the global teams, which interviewees associated with difficulties and inefficiencies in implementation work. Furthermore, the rotation of individuals changing positions was highlighted as a factor influencing the continuity of knowledge flow within the networks, acting as a potential source for knowledge gaps. When individuals leave their old roles, both globally and locally, interviewees described that certain important information from the network might go lost. The interviews highlighted that one cause for this may be that there is not a clear systematic structure that can transfer competence and knowledge when job rotation occurs. Another important aspect emphasized in relation to the network structure is the level of interest and

competence in the role assigned in which interviewees connected to participation and knowledge sharing practices within the network. Several interviewees emphasized the importance of having clear role descriptions especially when appointing a new person to the role.

The interviews also indicate variations in participation across sites, where some sites have a tendency of low participation in meetings and development activities. According to several global representatives, this may influence the ability to involve all sites in future development work and organizational learning activities, as such activities are often dependent on individual interest and willingness to engage in experimentation and new ways of working.

4.3.2.3 Awareness of Relevant Contacts Within the Network

The topic regarding years of experience one had with the network was also highlighted by the interviewees. The interviews mentioned that employees that have had extensive experience within the network may be more familiar with informal communication practices compared to a new member who may not be aware of these channels. Furthermore, the interviews indicated that when a member has limited knowledge in a specific area, a more experienced member may be more able to identify alternative ways of obtaining the necessary information, whereas a less experienced member will in most cases primarily rely on the network. Another interesting point mentioned by the interviews was the difference between the awareness of the network from a global and local perspective. An interviewee that first worked on the local level mentioned that it was more difficult to identify the right person to address a specific matter. They continued by explaining that when joining the global level, it was slightly clearer to know who to address or gather information from.

4.3.2.4 Gathering, Visibility and Communication of Local Initiatives

The interviews describe that the network system, including the yearly MTRM cycle, is closely connected to the collection of development needs from the local sites. Several interviewees discussed that information from local sites are used as input for determining global development activities. For the global team to appoint the development in direction that will benefit and be of interest to the sites, this input is seen as crucial according to the interviews. However, the interviews indicate variations in both the frequency and the level of detail of initiatives reaching the MTRM process. Several of the interviewees highlighted that some initiatives are communicated at a very general level, where the real challenge or problem for the development to solve is not clearly expressed. According to the interviews, this may influence how initiatives are interpreted and addressed within the process.

Furthermore, the interviews discussed that different local initiatives sometimes are being brought up to the MTRM by different roles within the organization. In the intended state, there is a clear structure of how the MTM networks, and more specifically the LTS roles, should be responsible for finding and expressing site needs into the roadmap. However, several of the interviewees working in global positions de-

scribed situations where multiple suggestions from local sites were submitted without local alignment. For example, the LTS contributed with one input, whereas the technical director of a specific site with another, completely different initiative or need. When discussing this occurrence further, interviewees described that different organizational roles may emphasize different perspectives when presenting initiatives. In the examples discussed, initiatives proposed by the LTS roles were often described as more technically focused, while inputs from directors were described more as broader in business orientation and value, but less technically detailed. According to the interviewees, these differencing may influence how plant needs are interpreted and prioritized within the process. The interviewees highlighted that this has been seen as a challenge for the organization, and that much effort has been directed recently to update the MTRM working format, where submitted initiatives are now expected to include more detailed information overall from the beginning of the process to enable for more efficiency and easier prioritization.

Another aspect emphasized in the interviews in relation to the gathering, visibility and communication of local initiatives, is the situation where development activities take place locally without any direct involvement from the global teams. As highlighted in several of the interviews, in this case there is a perception of “*initiatives going unrecognized*”, where the initiatives can be unknown to others than the ones working closest to it. One interviewee elaborated on this perspective by describing that due to the decentralized organizational structure, the global teams are not expected to have visibility of all ongoing initiatives across sites. However, there needs to be structures supporting knowledge flow despite this, which according to the interviewee is linked with leadership engagement and support. Reflecting if there are situations where information flows more easily between the local and global levels, interviewees highlight there seems to be two factors having an impact on the visibility and flow. The first factor is the size of the investment. For investment projects that do not require large financial support from the global budgets, there is a higher tendency of initiatives going unrecognized. Since each factory operates autonomously, they can decide the plans and investments of new technology out of their business reality. When projects go this way, there could be a risk of factories not sharing information regarding the implementation of a new technology solution as the global team might be disconnected from that development process. The second factor discussed in the interviews is the type of project in which the development is initiated. Several interviewees describe the perception that some technology development projects or implementations are “hidden” under product development projects. According to the interviews, product development projects are often more prioritized compared to pure process projects, which may result in technology implementations being managed within these projects rather than through dedicated technical development structures. This may according to the interviewees result in that certain technology implementations will not automatically be communicated and feeded to the global team in the format of MTRM and thereby in that way go unrecognized.

When discussing the flow and sharing of knowledge within the network, interviewees highlighted examples where existing information or technology solutions were not

easily accessible across the organization. For example, during a discussion of collaborative robots for a certain process, it was indicated that there were no such robots in the production environment today. However, later during a site visit, a robot that had similar attributes was found in another area. The interviewee described this as an example of knowledge being available locally, without being visible to the wider network.

4.3.2.5 Balancing Research Development Activities and Factory Urgency

Another aspect discussed in the interviews is how development activities are coordinated between global teams and factories during product launches. Several interviewees described that product launches often follow predefined timelines and milestones, which may influence how local sites interact with ongoing global development activities. According to the interviews, due to these strict cut-off times, pressure is put on the network, where local sites in some situations proceed with development activities independently rather than waiting for support or solutions from the global teams. Several interviews highlighted that this is a situation which is important to work with, and where communication and visibility of ongoing development work is of high importance. Trust between local and global actors was also described as an important aspect in relation to these interactions. To support this work, different approaches such as developing preliminary master processes and clear visualizations of development efforts are described as activities included in the global roles to coordinate and support alignment.

Another aspect that was brought up in several interviews was the perception of tendencies to the “not invented here syndrome”. According to the interviews, this relates to situations where locally developed solutions may be preferred over solutions developed elsewhere in the organization. Several interviewees associated this tendency with difficulties in introducing globally developed technologies or solutions at local sites.

4.3.2.6 Mapping of Development Activities Within the Organization

One aspect that was further discussed, which relates closely to the visibility of initiatives discussed previously, is the structural formal systems for mapping of initiatives. Several interviewees described that, besides the MTRM process and the structure of collecting and formulating technology development projects, there is currently no formal system that consolidates information regarding available equipment, completed tests and ongoing development activities at various sites globally. According to the interviews, currently only the projects that require support from the global teams, particularly financial support, are actively tracked and followed up. All other projects that are locally run are separated from this searchable structure and often stay siloed. For these types of initiatives, the network itself becomes the carrier of the information and knowledge, which according to the interviewees put a high dependency on the network to function as intended.

The interviews further highlighted situations where information and knowledge avail-

able in one function were not visible to other parts of the organization. Several interviewees described that when a problem or development need is highlighted, there may already exist relevant knowledge somewhere in the organization, but with the current structure it may not be directly accessible or identifiable. One example of this highlighted in interviews is that knowledge and experiences may remain within separate MTM networks, with little to no interaction across other networks. Some interviewees also reflected on whether more structured documentation practice could support the mapping of knowledge across the organization.

4.3.2.7 Coordination of Innovation and Existing Development Activities

In the discussion regarding having a process that both concerns developing existing technology and strategic long-term innovation, it was noted in the interviews that speed was seen as a crucial aspect. In today's fast-growing market, interviewees highlighted the importance of delivering solutions quickly. According to the interviews, combining different types of development activities may influence how work is managed. Several interviewees described that local representatives are often balancing operational responsibilities alongside global assignments, and that the time allocated to global assignments may vary between sites and roles. Some interviewees reflected on how the allocation of dedicated time may influence the opportunities for participation of broader network development and long-term coordination work.

Another aspect discussed in the interviews is that there seems to be differences in how the LTS role is interpreted and structured across plants. Several interviewees describe that even though there are formal role descriptions, local sites may organize the role differently, and that there are no formal structures available ensuring that the role is implemented consistently across sites.

4.3.3 General Insights from the Local Perspective

During interviews with local representatives, areas related to network coordination, knowledge sharing practices and technology development implementation were brought up. The local representatives highlighted situations where the intended organizational structure may be interpreted and applied differently depending on the local operational conditions. In this study, local representatives refer to individuals having the role of an LTS and technical directors from different sites in both Europe and South America.

4.3.3.1 Local Applicability of Globally Developed Solutions

An aspect that was brought up in the interviews with the local representatives is that the operational reality is shaped by different production processes across the competence areas, and in some cases also between sites that are working within the same production domain. Several of the interviewees described that there are large differences in automation levels, operational conditions and process maturity between sites. These differences may, according to the interviews, influence how globally

developed solutions are interpreted and applied across the organization. As recently introduced as a focus area in the organization, is the concept of “one problem, one solution”, as a mechanism for efficiency and scalability. Several interviewees highlight that re-use of solutions is generally welcomed and seen as an efficient way of working when introducing new technologies. However, several of the local representatives emphasized the prerequisites for it to function. With differences in suppliers, local systems and operational requirements, there are different factors influencing the applicability of solutions. One interviewee described how early involvement of local sites in development activities could support a better understanding of how different solutions fit different production environments.

As further discussed in the interviews, technology development and implementation is described as a process originating from clearly identified problems or operational needs, such as critical quality issues or ergonomic problems. In these situations, local teams rely on both internal and external networks to identify possible solutions. The interviews also highlighted that many of the local teams often explore technologies to some extent locally before involving broader organizational networks.

4.3.3.2 Time and Competence

Discussing the MTM network and the intended structure of technology development and implementation from the local perspective, several of the interviewees described that it can be difficult to balance the LTS role responsibilities, as it often becomes difficult to prioritize due to limited staffing and competing needs. The interviews indicate that the role is executed differently across sites, where in some cases the same role drives technology development, while in others they mainly maintain oversight of the development done elsewhere. Another aspect where interviewees indicate that time is a constraining factor is the MTRM process and its outcomes. Several interviewees highlighted that moving from an identified need to implementation may take a long time. It is common that it takes around one year for approval, followed by several years of research and integration of technology. According to the interviews, these long lead times create a situation where it is difficult to rely on the process for urgent needs.

From a competence perspective, interviewees highlighted the importance of local competence development in technology development. From a local perspective, some competence development may be required locally before reaching out to wider networks. If there is a clear problem or need, the network is contacted directly. If an opportunity emerges, such as new technology, the team normally explores a bit on their own before reaching out. Sharing with the network typically happens once the solution is sufficiently mature or if it is new to others. The MTM network is described as clear and working well and easy to use. For questions or uncertainties, communication is fast and accessible through meetings, phone, or emails. Some topics can be handled directly if readiness levels are high, while others involve more unknown areas giving rise to MTRM projects.

4.3.3.3 Roles in Technology Development and Network Input

When discussing the efficiency of the network, interviews with individuals having the LTS role described that it can be unclear what input is expected from the LTS roles into the network. While the formal role is defined, interviewees highlighted that there are limited guidelines clearly stating what deliverables or information should be fed into the network. In the local environment, there are always ongoing projects, however it is not clear what input is expected from the sites. According to the interviews, this may lead to variations in how information is shared and how the role is managed, as this is up for the individual LTS to discover.

When discussing the roles between the local and the global teams, interviewees emphasized that the global team should be responsible for technology development. When discussing the MTRM and possible additions to strengthen the work of technology development, it is found that the MTRM process in some ways can currently be used relatively reactive to support active needs. Since daily work at site level has little time for proactive search, the interviews highlight the preference of technology specialists from e.g. the global team to take on more responsibility for identifying new opportunities.

4.3.3.4 Communication, Visibility and Knowledge Sharing

From a local perspective, information and communication is described as having a vital role in ensuring curiosity and interest in the organization. A member of the local team emphasized the need to clearly describe what the solution will solve in the form of “selling” the solution clearly to the plants. Furthermore, they empathized that selling and promoting the message can spark more interest and curiosity in their plant. They explained that sharing information through a SharePoint list may in some circumstances lead to reduced interest.

Discussing with the local perspective regarding how technology development is carried out, the main area highlighted for when a new technology solution might be of interest to their processes is the situation where a clear problem is present, e.g. a quality or ergonomic concern, that can be solved with new technology. In a situation like this, the plant uses its network, either through internal or external channels, to find a solution. The network for this type of situation can be in contact with the formal internal network, such as driving the process through the MTM network, but there is also a network described more as a “relationship network” that seems to have high importance. This “relationship network” refers to people at the site having their own channels of people that they can connect to for a certain question, e.g. other factories with the same processes or people they are aware of that have insights to the topic. One interviewee explained that people tend to naturally lean towards discussion about a certain matter with somebody they already have built a relationship with. There is also the issue with finding the right contact person in the network due to the fact that the organization is relatively large. This in turn results in contacting a member that is already known and has already an established relationship with. However, the disadvantages that were brought up from the inter-

view is that your perspectives may become limited, as asking a colleague that you only turn to because of already established relationships may likely result in similar viewpoints.

A general viewpoint on the technology development that is highlighted from the site's perspective is that it can be difficult to find what is already developed somewhere in the organization. There are several processes supporting the way of working with collecting needs and how to budget for technology development. However, it is not as clear what is delivered in forms of results and technical solutions out of those processes. Regarding information needs in relation to technology development, interviewees described that the following aspects are particularly important from a local perspective, but that these are often missing or are vaguely described:

- The problem a technology is intended to solve
- Which performance indicators it targets
- The maturity level of the technology
- The cost of the technology and its suitability for the size of local operations

It was also mentioned that there is a wish for this type of information to be continuously updated so it can be aligned with current needs.

4.4 Emerging Coordination Efforts

This section presents emerging coordination efforts identified within the organization related to technology development and knowledge sharing. The focus is on recent initiatives and adjustments in organizational structures and processes.

4.4.1 Business Value Realization Network Establishment

The work with development and implementation of Vision System based technologies is one area in which the organization has faced challenges in organizational learning and knowledge sharing across functions. The term Vision could be seen to be equivalent to AI in terms of providing broad capabilities, where the technology is applicable in a wide range of manufacturing applications such as robotic guidelines, process monitoring, quality defect detection etc. Furthermore, the technology has different solutions providers available on the market, who can either provide software, hardware, turnkey or system integration solutions. The abundance of solutions creates the possibility of having different solutions available that may be applicable for the different production processes at TTI.

As found in the technical development of utilizing Vision Systems within Volvo Group, there is no formal decided solution referred to as the best practice. There are several available user cases, with different application areas and techniques, and available suppliers are both internally developed systems such as Volvo Vision

System and several different external suppliers. The low degree of standardization (no current “best-practice” A/B/C level documented) has led to a situation of duplicated work and few lessons learned from both successful and unsuccessful work across different sites.

Several interviews with key stakeholders working with computer Vision Systems in different parts of the organization highlight the changing nature of the question. Previously, the level of coordination was low, and the network structures had few interactions leading to no knowledge in an actionable format for sites across the organization. There has been some documentation regarding solutions, examples and user cases (mainly for Volvo Vision System) stored in SharePoint available upon request or to relevant stakeholders. However, there has not been a clear knowledge sharing structure in place having responsibility for collecting and coordinating cross-functional needs and knowledge. This has probably led to much of the work being stored in silos within the different MTM networks globally. The CoC that was highlighted as “Vision Systems” was solely this documentation forum mentioned above, not the coordination or needs based version across several Vision Systems.

As indicated in the interviews, extensive work is currently taking place to re-structure the way of working related to computer-based Vision Systems. Within this work, several of the key stakeholders across the organization are involved, such as MTMs from Powertrain and Vehicle, representatives from other business areas such as Construction Equipment, and MTS representatives across the organization with specialized technical knowledge. One interviewee, with a main responsibility for leading this work, emphasizes the efforts and focus on strengthening the business perspective within computer vision initiatives. A key ambition has been to establish an overarching structure that connects technical development with business ownership and IT departments. Since vision solutions are directly linked to IT systems, IT involvement is considered critical. To address this, the new structure called the Business Value Realization Network (BVR) has been established in a way that connects all these important stakeholders. To create this connection, business owners from all relevant competence areas are appointed, having responsibilities to involve and communicate the perspectives of the MTM and MTS representatives towards the broader network. One important difference in this new network compared to the scope of the previous CoC forum is that within this network, both internally and externally developed solutions are covered.

Previously, one major problem was that sites acted independently, with weak alignment both across sites and with IT. In some cases, sites progressed with supplier solutions that later could not be integrated by IT, or that conflicted with other MTM network decisions, resulting in late-stage rejection due to misalignment. To prevent parallel and uncoordinated solutions, this new BVR network should work closely with existing structures, processes, and networks. The baseline for the BVR network to function is the already pre-existing MTM networks, which are important for the connection to the different sites representing different production processes. The long-term goal is that all decisions should follow the correct governance paths with greater transparency and awareness of initiatives across business areas. This

includes that all investments above a certain threshold, or those impacting master processes, should be reviewed and confirmed by the MTM network, leading to a natural entry point of both current needs and future development needs for the BVR network.

Discussing the roles of the pre-existing forums available for cross-functional coordination, TASC has been mentioned as the key forum connecting competence areas and other organizational units. However, as indicated in multiple interviews with people having MTM/MTS roles, the role of TASC seems to have evolved significantly over the past years. Previously, TASC was more technically oriented, but today it is positioned as a higher-level forum focused more on alignment and investment decisions in externally funded projects. A mismatch between the forum level and the specialized expertise of the participants involved has led to decisions regarding technologies being pushed back down to organizational and network levels, where connections between areas are low. The current model emphasizes continuous, focused dialogues within specific technology domains, developing roadmaps based on deep technical and operational knowledge rather than in forums that are far off in that competence.

Moving from an informal setting towards a more formal structure the interviewee highlights that there will always be a need for various informal forums to complement other structures. Due to the high complexity and multiple organizations engaged in technology development there is therefore a need to connect with all ongoing activities. Outputs from these initiatives need clear routes back into formal networks. A key risk identified is that CoC may independently drive technology development that is not aligned with agreed roadmaps in formal networks.

The new process that is created is forward-looking, focused on anticipated needs and improvement potential in existing solutions rather than reacting solely to current issues. For computer vision specifically, the ambition is to move toward appointed, fully integrated solutions within Volvo's systems. A central catalog of approved solutions is envisioned, allowing users to select appropriate solutions based on defined needs. A significant challenge is the lack of visibility over existing computer vision solutions and use cases. To address this matter a mapping has been initiated which consists of requesting information on applications, systems, technologies and use cases across the organization. The goal is to build a searchable catalog that allows stakeholders to identify suitable solutions rather than starting from scratch.

For long-term sustainability of the network the interviewee highlights the need to both engage employees and deliver tangible user value. If site questions can be addressed directly through existing solutions, sites are relieved from having to search for suppliers themselves, significantly shortening the implementation lead time. Training is also critical, ensuring that solutions are not only delivered but effectively embedded into daily operations. Solutions should be easy to find, with clear ownership, support structures, and contact points. One of the recurring issues historically has been to put insufficient attention to identifying which stakeholders and skills at site level to maintain solutions. In cases involving immature technol-

ogy, sites often purchase turnkey solutions, leading to a lack of in-house knowledge. When problems arise, suppliers must be re-engaged through different small technical development projects, increasing costs, and complexity. Better documentation of implemented solutions is therefore seen as essential for effective support and long-term operation.

The importance of making projects visible to networks is emphasized repeatedly and across interviewees. Networks are described as the foundation for organizational learning, site engagement, and sustained results. When networks do not function as intended, broader processes also tend to fail. While the organization has access to large amounts of data, the remaining challenge lies in turning that data into actionable, well-governed knowledge that supports strategic and operational decision-making.

4.4.2 Changes in the MTRM Input Format

Another area in which the coordination of initiatives for technology development has been challenging is for the collection of needs to the yearly Manufacturing technology roadmap (MTRM) cycle. This is exemplified through the perception that different roles in the organization have different ways of proposing initiatives to the MTRM roadmap. In the intended state, there is a clear structure where the MTM networks, and more specifically the LTS:es should be responsible for finding and expressing site needs into the roadmap. However, as indicated by several of the interviewees working in more global positions there sometimes comes several suggestions from the local sites, which are not aligned. To work with this, a new format for the MTRM collection of ideas has been established. The new format is an open SharePoint for all working with MTRM related questions, where all actors regardless of having global roles, local roles or others can submit suggestions directly into the SharePoint. Previously, suggestions from other local roles were included from the side, e.g. through other informal contacts. In this new format, there is also a higher focus on the problem description and the specified needs, as this is seen as important for developing the correct solutions.

5

Analysis

This chapter presents the analysis of the empirical material, through which the findings of the study are generated. The analysis is conducted in relation to the theoretical framework, which structures the analysis around four categories: knowledge creation and transfer, learning flows across organizational levels, depth of learning and balance between exploration and exploitation. The analysis is structured to answer the research questions and to address the aim of the study, which is to understand how organizational learning can be strengthened at Volvo Trucks Technology and Industrial Division.

5.1 Knowledge Creation and Transfer

This section focuses on knowledge creation and transfer as a perspective for analyzing organizational learning. Knowledge creation refers to the process through which new knowledge is developed, while transfer concerns how knowledge is shared and made accessible in an organization. The section is based on Nonaka's (1994) SECI model, which is used to analyze how knowledge is developed and moved across different levels in the organization.

5.1.1 Challenges in Moving to Externalization Phase

New knowledge is generated and utilized through constant interaction between tacit and explicit knowledge (Nonaka, 1994). In the SECI model, the socialization phase enables learning through shared experience and constant interaction between individuals while externalization refers to the process of taking that tacit individual knowledge and converting it into shared explicit group knowledge (Nonaka, 1994; Nonaka & Konno, 1998). If the transfer between the socialization phase and externalization phase is inadequate, there is a risk of knowledge remaining only at the individual level.

The transition from socialization towards externalization in which individual knowledge becomes group knowledge is considered an important step for effective organizational learning. As part of this process Nonaka and Konno (1998) argues that the sharing of experience in an understandable way plays a crucial role for moving between the phases. However, the empirical findings indicate that this transition is

not only dependent on willingness to share knowledge, but also on how interpersonal exchange is structured within the organization. The empirical data shows that individuals often emphasize *“the choice of personal relationships or informal networks”* when engaging in knowledge sharing. This means that discussion about technical or operational details are often directed towards stakeholders which the individual already has built a relationship with. By doing so the individual gains valuable insight that may be used to further develop their own expertise. This aligns well with Nonaka (1994) explanation, in which the author explains that in the socialization phase the individual shares tacit knowledge through constant interaction with others which results in new insight being developed among the individuals. At the same time, the reliance on these relationship networks appears to shape how knowledge moves beyond the interaction in which it is created. As indicated by Nonaka and Konno (1998) individual tacit knowledge should be shared and transformed into a group’s explicit knowledge. While personal relationships enable rich and efficient exchange of tacit knowledge, they also risk knowledge getting stuck within specific interpersonal contexts. Knowledge that is shared at the socialization level may not necessarily be translated into explicit and transferable group knowledge, limiting the shift towards the externalization process. One example of this can be described when the local initiatives are not shared to the MTM network. In several cases, the MTM or MTS seems to be unaware that a plant has already implemented a specific solution, as for instance quotes from the interviews highlighting that *“local representatives may not share or communicate the full implementation details”*.

Sharing experience and engaging in discussion with others are seen as important mechanisms when aiming to build a more combined knowledge within organizations (Kahrens & Früauff, 2018). However, the empirical findings indicate that this process is constrained by limitations in clarity of who the individual should involve in a specific discussion or knowledge-sharing process. Several of the interviewees from the global perspective highlighted this challenge, for example through statements such as *“employees with many years of experience often rely on experience-based networks to identify relevant stakeholders, whereas newly hired employees may find this challenging, leading to a more heavily reliance on the formal networks”*. This challenge further extends beyond individual experience levels, as it is also described as *“difficult to identify the right person to address a specific matter”* at the local level. This indicates that uncertainty where to direct knowledge sharing and discussion to enable more effective organizational learning does not only affect newcomers, but also more broadly in the organizational structure. These challenges further indicate that the uncertainty in who to involve could lead to that valuable insights may never reach the appropriate individuals or platforms for broader distribution. From a theoretical perspective, this reflects the importance of interaction and communication channels in enabling the transition between tacit to explicit knowledge, supporting the transition between phases in the SECI model (Nonaka, 1994).

5.1.2 Challenges in the Combination Phase

The combination phase involves several steps, such as gathering, modifying, structuring and sharing explicit knowledge within the organization, with the aim of trans-

forming existing explicit knowledge into more systematic and usable organizational knowledge (Nonaka & Konno, 1998; Kahrens & Früauff, 2018). This phase therefore depends on the ability to collect knowledge and integrate them into coherent systems that can be accessed and used across the organization.

The empirical findings show that the organization uses several forms or mechanisms to support this process, including master processes, manufacturing technology roadmap (MTRM), network meetings and different SharePoint platforms to capture knowledge. However, as indicated in the interviews, there is a lack of a clear and structured way to gather and integrate the different knowledge across different sources. A reoccurring theme in the empirical data is that there is a distinction between different types of projects, highlighted in quotes such as *“there is a clear difference in pure process development projects and product development projects”*. As explained by the interviews, process driven development projects or initiatives are more systematically captured through the MTRM structure, while product related technology development is often embedded in parallel structures that are not directly linked to formal knowledge capture systems or formats. This creates a situation where explicit knowledge is generated across multiple platforms but not consistently integrated into a unified structure, which limits accessibility and makes it more difficult to combine insights to a coherent overview. These findings align with how Nonaka and Konno (1998) argues that for the combination phase to be carried out effectively and lead to increased organizational learning, it is important that the different explicit knowledge are available, collected and combined into a more coherent form that others can utilize.

Another finding that could be analyzed is that two different local initiatives are being sent to the MTRM. The interviews highlighted that *“LTS contribute with one input, where the technical director of a specific site with another, completely different initiative or need”* which also the interviews continued with explaining could lead to difficulties in determining what the sites really want. This could be interpreted that the organization may lack a well defined process for gathering the explicit knowledge from the local level which may limit the ability of forming it into more coherent systems that clearly forms an understanding of the site’s specific needs.

5.1.3 Challenges in the Internalization Phase

The internalization phase describes how individuals within an organization take explicit knowledge that was generated from the combination phase and transform it into their own tacit knowledge (Nonaka & Konno, 1998). For this transition to be effective explicit knowledge needs to be clearly gathered and structured so that individuals can understand and apply it in their specific context.

The empirical findings indicate that the organization has some challenges in ensuring that explicit knowledge is consistently structured and made available in a way that supports this transition. The challenges in the combination phase, including a lack of clear and structured ways of gathering and creating coherent formats for explicit knowledge, appear to continue to the internalization phase, where existing knowl-

edge does not always become usable in practice. Interviewees describe situations where explicit knowledge exists, but there are issues in utilizing that knowledge further. One example of this is the case with implementing and learning organizationally about Vision Systems. With several explicit knowledge gathered, but without a coherent and successful combination phase, a lack of best practice documentation and visibility of existing solutions has occurred. This in turn resulted in duplicated work being carried out, as well as difficulties in using that knowledge and transforming it into new tacit knowledge. As described by Nonaka and Konno (1998) an effective transition between the combination phases and internalization phase requires systematic explicit knowledge that the individuals could utilize to support their own “learning by doing” process. When this link is weak, the cycle of knowledge creation risks fragmentation, where organizational knowledge cannot be converted into new tacit insights further supporting the learning process.

Another interesting finding worth pointing out, that may have an impact on the success of the internalization phase, is the knowledge gap between levels. Nonaka and Konno (1998) explains that the individual must understand which knowledge is applicable in their domain in order to use it and transform it into their own tacit knowledge. As discussed in interviews with representatives from the global perspective, one challenge seems to be that the local sites in some circumstances choose not to implement a globally developed solution directly. There has been speculation as to why this occurs, where the interviews highlighted possible causes such as *“lack of understanding at the local site regarding the technology solutions value”*, or *“insufficient financial capabilities and training within the factories”*. Statements from interviews such as *“there is a lack of understanding at the local site regarding the technology solutions value”* align well with Nonaka and Konno (1998) explanation, where the author explains that the individuals must understand which knowledge is applicable to them in order to transfer into new tacit knowledge. This in turn could therefore be interpreted as a weak transition between the combination and internalization phase as the knowledge obtained through explicit knowledge is not actively transferred into new tacit knowledge.

Nonaka and Konno (1998) emphasize that all phases of the SECI model and also specifically for internalization, individuals must understand the knowledge in order to make use of it. As indicated in the empirical material, development projects are in some cases described as being far from the current operational reality at sites, which limits how easily explicit knowledge can be interpreted and applied. The different factories are operating with different maturity levels, handling different variations as well as having completely different production processes. This suggests that the same explicit knowledge cannot be assumed to be understandable across all sites. Therefore, for the internalization phase to be effective, the focus should not only be on making explicit knowledge available, but also how it is communicated and framed to support different contexts. This highlights the need to adopt how knowledge is formulated, so that it can be effectively transformed into tacit knowledge in the cautious learning cycle.

5.1.4 BVR Network for Knowledge Creation and Transfer

Nonaka and Konno (1998) explains that effective translation between socialization, externalization, combination and internalization could enable that knowledge to be transferred and shared across the organization. Furthermore the SECI model is seen as a continuous drive process that should occur and transfer knowledge continuously.

As demonstrated in previous sections, several aspects related to the SECI model remain insufficiently developed which may hinder effective knowledge creation and transfer. The empirical findings indicate that the initiatives often remain localized, with no clear mechanisms that can ensure to gather, systematize and share the knowledge across the organization in an effective way. In response to these identified limitations recent organizational development is also seen from the empirical data, which appears to be a possible way to improve how knowledge is being shared and structured across the organization. From the empirical findings, one such development which may result in improving the sharing and transfer of knowledge is the new network for Vision Systems. As described in the empirical data, Vision System is a technology where the organization has seen multiple duplications in learning, clearly showcasing the difficulties going between the different steps in the SECI model. The term Vision System can be seen as a broad technological domain, with several available applications for different processes. The situation was characterized by multiple solution providers both internally and externally, however with a lack of consistent documentation and consolidation across organizational units. As a result, the organization had struggles with sharing common understanding and taking benefits from lessons learned of both successful and unsuccessful implementations.

As now seen through the interviews with stakeholders in the network related to the work with Vision Systems, a new structure of working is emerging. This new structure is called Computer Vision Business Value Realization Network (BVR) and is constructed in a way that aims to gather both internal and external solutions and provide a more complete organizational wide perspective which in turn hopefully result in shared learning. Much of the initial work with this structure has been to include key stakeholders, such as representatives with specialized technical expertise in the domain, including relevant MTM/MTS individuals as well as IT owners. Nonaka (1994) described that tacit individual knowledge in the socialization phase could be achieved through sharing experience and having close interaction with others. The empirical findings showed that through this structure in which there are more appointed individuals in the organization, can be a possible strengthening of the socialization phase since it increases visibility and identification of relevant stakeholders to share information with.

Sharing tacit knowledge with others through constant interaction is seen as important in the socialization phase, as it can enable knowledge transfer (Nonaka, 1994). The empirical data indicates that in the BVR network, once a site wants to know more or implement a Vision System solution, the network should be addressed as the main contact point before implementing the technology. By doing so, it enables that knowledge does not remain local but rather that the knowledge is shared much

earlier among different individuals, which in turn could lead to less duplicated work.

Furthermore, the new network structure could also be seen to potentially improve the externalization phase. As explained by Nonaka and Konno (1998) externalization aims to turn individual tacit knowledge into a group's explicit knowledge. The findings indicated that a prerequisite for the network to function in the long run is to map the current situation regarding Vision Systems.

This work has been initiated with a mapping of all implemented applications, systems and user cases within the domain, which all together will enable the creation of a coherent platform. This mapping aims to ensure that all implementations of the Vision System are collected and can be shared within the BVR network. To allow for this network to function, business owners are appointed from all relevant global MTM networks, who are responsible for collecting relevant insights that concern Vision Systems into the BVR network over time. Having an appointed business owner opens the possibility of ensuring that valuable local insights are being brought towards cross-functional forums. Ensuring that the individual insight becomes the group's collective knowledge is seen as vital in order to gather and transfer the knowledge further (Nonaka & Konno, 1998). From the empirical data by both mapping, appointing business owners and sharing the local initiatives enables a better transition from individual to more group documented knowledge. However, important to notice for the BVR network to function as intended, the functioning of MTM networks is crucial as these should serve as the main link between the global structure for coordinating across organizational boundaries and the local sites.

The mapping of current implemented applications could also be interpreted as a step towards strengthening the combination phase. Nonaka and Konno (1998) explained that the combination phase should aim to turn existing explicit knowledge into more systematic knowledge. The findings show that, before the BVR network, there was not a systemic way of showing what type of solutions were available within the organization. The BVR network aims to construct a shared catalog that shows approved and already tested solutions. By doing this, it is illustrated that different explicit knowledge obtained in the organization are being formed into more systematic explicit knowledge.

Lastly, the internalization phase from the BVR network may also be strengthened. The internalization phase aims to transfer the systemic explicit knowledge into new tacit knowledge at the individual level (Nonaka & Konno, 1998). The empirical data explains that by having a catalog of approved solutions along with clear explanations and stakeholders contacts, opens the possibilities of the individuals understanding which solutions available in the market but also which solution is more applicable to them. This indicates that there will be a systematic explicit knowledge in the form of a catalog that the individuals then will use and transfer into their own tacit knowledge. Important to note which is explained by Nonaka and Konno (1998) is that in order for a good transition between the combination phase and internalization phase, the individuals must understand which knowledge is applicable to them in order to turn it into their own tacit knowledge. Ensuring that the catalog is un-

derstandable and applicable to all the different factories, allows that the knowledge obtained from it could be used more effectively within the organization.

5.2 Learning Flows Across Organizational Levels

This section focuses on learning flows across organizational levels as a perspective for analyzing how organizational learning develops and becomes embedded within structures and routines. The section is based on the 4I framework developed by Crossan et al. (1999), which is used to analyze how knowledge is shared and how learning flows across organizational levels within the manufacturing technology process.

5.2.1 Barriers to Feed-forward Flow

According to the 4I framework, feed-forward learning refers to the process in which new insights and locally developed knowledge move from the individual level towards group levels and further to the broader organizational integration and institutionalizing (Crossan et al., 1999). For this process to function effectively, knowledge must become visible, communicated and accessible beyond its immediate context. Crossan et al. (1999) further emphasize that organizational structures and mechanisms play an important role in enabling this upward flow of learning across levels. When such mechanisms are weak or fragmented, learning risks becoming constrained within smaller groups rather than contributing to the organizational learning overall. Later extensions of the framework further argue that organizational learning in the feed-forward flow is not only shaped by formal structures, but also by relational dynamics and power (Crossan et al., 2011; Lawrence et al., 2005).

The empirical material indicates several barriers that may constrain this feed-forward flow within the manufacturing technology process. A recurring pattern across interviews is the limited visibility of locally developed initiatives where solutions or technology development projects frequently fail to become visible beyond their immediate context. This can be connected to the challenge identified by Crossan et al. (1999), where learning becomes stuck between levels instead of moving toward broader organizational integration. One example from the interviews of this challenge in the organization is the occurrence of local sub-optimization, where solutions often are developed to solve site-specific needs but remain decoupled from global needs. Observations show that external actors, such as suppliers, often introduce solutions to the local sites that are overly expensive and poorly aligned with global needs, and also decoupled from internal support structures. While these solutions often result in short-term value at site level meeting the requested need, they tend to on the broader level reinforce divergence and duplication of learning. Once the solutions are implemented they tend to stay and exist in silos as separate site projects, which indicates that they are not systematically integrated into broader knowledge structures or shared platforms.

Crossan et al. (1999) argue that feed-forward learning depends on mechanisms that

enable individual or local insights to be shared and translated across organizational boundaries. However, the empirical material indicates that knowledge sharing often occurs within smaller networks. While some initiatives remain strictly local, others are transferred into MTM networks as intended, but contrasting to the intended flow, these initiatives tend to remain contained within these networks rather than diffusing further across the organization. This is reflected in statements such as “*activities remain local in that MTM network*” and “*most of the projects are run within only one MTM network*”, indicating that the available cross-site structures mainly connect a limited set of factories. From a 4I perspective, the mechanisms supporting feed-forward learning appear to function more as localized learning groups, rather than mechanisms for organization-wide learning integration. Although cross-site collaboration exists, its scope seems to be limited to sub-groups, which may constrain knowledge moving towards institutionalization at broader organizational levels. The challenge is therefore not interpreted as a lack of learning processes, but rather the learning getting stuck within network boundaries. As argued by Crossan et al. (1999), network or level boundaries often limit broader organizational integration making reuse of knowledge challenging.

The empirical findings also indicate structural barriers related to knowledge visibility and retrieval. Crossan et al. (1999) emphasize that institutionalizing requires learning to become embedded within organizational systems, routines and structures. However, several interviewees described difficulties in identifying existing solutions within the organization. For example, quotes such as “*it is difficult to find what is already developed somewhere in the organization*” or “*there is a lack of clear mapping within the organization*”, suggest that even when solutions exist in the organization, the organization lacks sufficient mechanisms for retrieving and diffusing it across levels. Contrasting this to the intended state, there should be a formal structure with searchable solutions for knowledge sharing through the MTRM process and associated SharePoint systems. However, the empirical material indicates that these structures mainly capture and cover projects that require global support, whereas all other projects are separated from this searchable structure. As a result, many of the locally generated solutions or learning remain outside of formal databases or tracking systems, preventing it from contributing to cross-functional learning. From the perspective of the 4I framework, this weakens the transition from group level to organizational level, as the knowledge generated in one part of the organization cannot be reused, coordinated or scaled if it is not formally visible in organization-wide systems or structures.

From an extended 4I perspective, organizational learning is not only shaped by formal learning processes and mechanisms to embed learning into structures, but also by structural and political dynamics which influence what knowledge is made visible, legitimized and integrated across the organization in the feed-forward learning (Crossan et al., 2011; Lawrence et al., 2005). This implies that certain projects and knowledge domains may receive greater organizational attention, which in turn may affect how individual or group level learning is translated and embedded into the more formal structures. One example of an empirical pattern reinforcing this challenge is that some technology development efforts are, as indicated in interviews,

“hidden under product development projects”, rather than being communicated as process or manufacturing technology projects. Since product development projects tend to receive higher prioritization, technology implementations are sometimes carried out indirectly through these structures instead of the formal manufacturing technology channels such as the MTRM process. From a 4I perspective, this suggests that some important learning processes may bypass formal organizational learning structures entirely and instead rely on local actors and informal networks. With these initiatives not formally captured within manufacturing technology processes, the learning risks becoming weakly institutionalized and less accessible across organizational levels.

5.2.2 Breakdowns in the 4I Processes

The 4I framework conceptualizes organizational learning as a process where individual insights are gradually developed through interpreting and integrating at the group level to ultimately be embedded into organizational systems through institutionalizing (Crossan et al., 1999). A key assumption in this process is that shared meaning is established at each stage, enabling learning to move across levels. When this alignment is weak, learning may become fragmented, often leading to failure in progressing towards organizational embedding of learning.

The interpreting phase is according to Crossan et al. (1999) the process where first individuals start to make sense of their insights, and further also translating this into a shared understanding within a group. If shared interpretation is not achieved, interpretations may remain fragmented and dispersed across individuals and contexts, which disrupts the transition from individual sense making to collective integration. This may even further constrain the development toward organizational level learning. As indicated by the empirical findings, there are situations in the organization where role definitions and responsibilities are characterized by some sort of ambiguity. Relating this to how the 4I framework strongly highlights the process of creating shared understanding as a necessity for moving towards integrated and institutionalized learning, such ambiguity may influence how technologies, needs, and prioritization are understood at different levels, affecting the overall process of organizational learning. One illustrative example of this, highlighted by both global and local stakeholders, concerns the role of the LTS within the MTM network. Although a formal role definition exists, there is as cited from one of the interviews *“no clear definition of what deliveries are expected to be fed into the network”*, resulting in inconsistent practices across the sites. From a 4I perspective, this suggests that the interpreting process remains uneven across the organization, where the same formal role is assigned different meanings and priorities depending on local context. This creates an unbalanced network situation, in which learning inputs and responsibilities vary between sites. For processes created with the assumption of similar input across sites, e.g. as for the MTRM yearly cycle this could hinder a uniformed and integrated working process, which is required for achieving effective organizational learning.

Extensions to the 4I framework also highlight leadership as an important factor in-

fluencing how learning is enabled or constrained across levels (Crossan et al., 2011; Vera & Crossan, 2004). At the individual level, leadership can encourage learning by fostering experimentation and openness to new ideas, while at the group level it shapes how communication and knowledge sharing takes place within and across teams. At the organizational level, leaders influence which knowledge is prioritized and ultimately becomes institutionalized into organizational structures and routines. Applying this perspective to the empirical material, variations in how the LTS role is enacted across sites may therefore not only reflect ambiguity in formal role descriptions, but also differences in how local leadership supports and prioritizes learning activities. As stated by one of the interviewees *“some sites allocate much resources to the role, while others do not even have an assigned LTS”*. From this perspective, leadership does not only affect whether learning takes place, but also how consistently learning processes are enacted. From a 4I perspective, these differences in leadership engagement may contribute to uneven participation in shared learning and coordination processes across the network. The empirical findings indicate that certain actors or sites take a more central role in driving learning activities, while others remain less connected. This may influence how consistently learning processes toward wider organizational integration and institutionalization.

Crossan et al. (1999) emphasize that interpreting and integrating processes depend on the development of shared cognitive maps, which are shaped by differences in roles, experience, and context. This may create conditions where multiple interpretations of the same organizational structures exist simultaneously, known as the challenge of equivocally, which can make it more difficult for learning to progress across levels as integrating and institutionalizing relies on shared meaning and coordinated understanding. This variation in interpretations is reflected in the empirical findings related to the center of competence (CoC) structures. The CoCs were initially designed as relatively loose structures intended to enable aligned knowledge transfer across the organization, with few formal rules regarding participation and meetings formats. However their intended purpose included that each CoC should define and own a roadmap for new technologies, including ongoing initiatives, needs and status updates on the cross-functional TASC forum. Contrasting this to how the work with the CoCs is actually conducted, there seems to be relatively large differences between different focus areas. Interviews suggest that while some CoCs focus heavily on early stage development and awareness creation, others have evolved into more structured and coordination forums. From a 4I perspective, this suggests an uneven interpretation of the CoC role, where the same structure supports different learning logics across contexts. This is further reinforced by a gap between the intended and actual function. While CoCs were envisioned to own a roadmap for new technologies, in practice *“it lacks formal authority to do so”* and is instead described as *“primarily serving as a resource hub”*. These differences are further shaped by structural conditions, as coordination is constrained by *“different budgets and priorities across networks”*, which limits the ability to develop shared roadmaps and aligned practices. This limits coordination at an organizational level and may reduce the ability to translate knowledge beyond specific groups. Without a unified or shared approach, the input will be in different forms, which may impact the pos-

sibility of moving insights from a local or domain specific context towards broader integration and institutionalizing, as described by Crossan et al.(1999).

At the institutionalizing stage, learning is expected to become embedded into organizational structures, systems and routines (Crossan et al., 1999). In the empirical material, the MTRM yearly process represents an attempt to support this transition, as it provides a shared structure across MTM networks and organizational functions. However, while this process supports coordination at the integrating level, challenges emerge when learning is expected to be translated into formal organizational decisions. As part of the MTRM process, one step is alignment at TASC level, which represents the formal governance structure in the wider organizational network. While TASC is intended to support coordination and decisions at a higher organizational level by aligning competence areas, it is described in the interviews as being *“more focused on management-related topics and external investment projects and less suited for detailed technical discussions”*. This shift in focus has, according to interviews, occurred in recent years and has led to that decisions and discussions on more detailed technical solutions and development has been pushed back to the MTM networks. These insights indicate a structural gap in the institutionalizing stage, where available governance mechanisms do not consistently enable the translation of technical knowledge into formal organizational decisions and embedded structures. Instead, knowledge that is generated and partially aligned in earlier stages remains within network-level domains, rather than being institutionalized at higher organizational levels. From a 4I perspective, this suggests a breakdown in the transition between integrating and institutionalizing, where learning is not fully translated into organizational systems and standards, possibly due to the gap leaving no formal decision forums. The emergence of new initiatives such as the Computer Vision Business Value Realization Network (BVR) can be interpreted as an attempt to address this gap. The BVR network consists of assigned formal roles including stakeholders from all relevant competence areas, with the aim of enabling effective gathering, sharing and structuring of all initiatives concerning the vision technology.

5.2.3 Barriers to Feedback Flow

According to Crossan et al. (1999) organizational learning can be described as a dynamic process that moves in both feed-forward and feedback directions, where institutionalized knowledge is expected to shape understanding and guide action throughout the organization. For feedback learning to be effective it is not sufficient for knowledge to just be formalized knowledge in systems and structures, instead such knowledge must also be interpreted as relevant and actionable for individual or group levels. As highlighted by Crossan et al.(1999) organizational learning is not fully achieved through formalization of solutions alone, but also depends on how these solutions are interpreted, understood and enacted across organizational levels. With bottlenecks in the learning flow, there is a risk that organizational learning becomes constrained as knowledge cannot move effectively between levels. As indicated in the empirical material, there seems to be challenges related to this downward flow of learning in the manufacturing technology process. Interviewees

from the global perspective describe difficulties in translating globally developed process solutions into local implementation. While many technology development projects have progressed through the early MRL phases in the development teams, challenges emerge when moving toward implementation at site level. According to several interviewees, projects often “*struggle to find a recipient in a factory*” where competence gaps and limited understanding of the technology’s potential constrain further implementation. This indicates that even when knowledge is developed, formalized and partly institutionalized through master processes, completed projects or shared databases, it does not consistently reach or become actionable knowledge at the local level. From a 4I perspective, this could be seen as a breakdown in the feedback process, which might have a negative impact on the learning process.

Another indication of a breakdown in the feedback learning process can be identified in the tension between how technology development is perceived at global and local levels. From a local perspective, one of the interviewees expressed that “*the global team should work more with technology development because the sites have limited time for it*”. At the same time, the global perspective indicates that such development is already taking place, all the time. This suggests that the perceived lack of support is maybe not necessarily because there is insufficient technical development, but rather due to barriers in the learning flow from the global levels to the local levels. One interesting aspect to deep dive into for this challenge is the barriers to the interpreting process. Local sites seem to often lack the contextualized understanding which is needed to be able to assess how a global solution fits their specific operations. As highlighted in the empirical findings, there is a need to clearly communicate “*the problem a technology is intended to solve*”, “*which performance indicators it targets*” and “*the cost and suitability for local operations*”. Without this type of contextualization, globally developed solutions are hard for the sites to translate into actionable initiatives at site level. This, taken all together, shows that for feedback learning to function effectively, it is not sufficient to only develop and distribute solutions, the knowledge must also be interpreted in relation to local needs and constraints. In line with Crossan et al.(1999) this highlights how important it is to link integrated or institutionalized knowledge back to individual and group-level understanding. Allowing this link to be weak, will be a risk, as it can lead to institutionalized solutions being ignored, misunderstood, or replaced by locally developed alternatives.

For learning to flow in both directions, Crossan et al.(1999) argue that shared understanding is of high importance also in ensuring effective feedback learning. The empirical findings indicate that for some initiatives feedback learning functions better than for others. In relation to master processes and standardized requirements, the feedback learning process appears to function effectively, as clear expectation, compliance needs and formal structures provide a strong basis for institutionalization and downward dissemination.

5.3 Depth of Learning

This section focuses on the depth of organizational learning as an analytical perspective. The section is based on the concepts of single-loop and double-loop learning originally developed by Argyris and Schön, where the concepts are used to analyze the extent to which learning within the manufacturing technology process occurs.

5.3.1 Single-loop Learning in Local Operations

Argyris and Schön describe single-loop learning as a process where errors are detected and corrected without questioning the underlying assumptions, values or norms (Auqui-Caceres & Furlan, 2023; Basten & Haamann, 2018). Rather than reflecting on existing ways of working and how to improve, learning primarily focuses on restoring performance and solving problems within current structures and routines. One indication from the empirical findings related to the concept of single-loop and double-loop learning, is the perception that learning at the local sites is mainly driven by problem-solving needs. As described in one interview with a local representative, *“we usually start looking for new solutions when there is a problem that is affecting production. We guide our actions based on the SQDCP standard so if there is a quality issue, ergonomic issue or similar we have to take action to not risk our performance”*. This pattern of problem-solving could be interpreted as sharing some common characteristics with single-loop learning. As described by Auqui-Caceres and Furlan (2023), single-loop learning is often a problem-oriented process that emphasizes quick correction where learning is primarily aimed to restore performance rather than enabling deeper reflection. While the empirical data does not cover the topic deeply enough to make any definitive conclusions regarding whether underlying assumptions are questioned or not in these cases, it could be an interesting aspect to take into consideration when discussing the situation regarding organizational learning overall.

5.3.2 Structures Enabling Double-loop Learning

In contrast to single-loop learning, Argyris and Schön conceptualize double-loop learning as a process that does not only correct errors, but where are also the underlying assumptions are questioned and potentially modified (Auqui-Caceres & Furlan, 2023; Basten & Haamann, 2018). This implies that organizational structures that support double-loop learning are expected to enable reflection on long-term needs, facilitate cross-level knowledge sharing and support adaptation of existing structures and routines. As indicated in the empirical findings, there are several mechanisms that are intended to support deeper learning in the manufacturing technology process work, such as the Manufacturing Technology Roadmap (MTRM) and Center of Competence (CoC). Both structures are intended to support reflection and modification of existing systems through process development, as well as enabling knowledge sharing across sites. However, the findings further suggest that these mechanisms are not consistently effective in creating deeper learning, as they are often bypassed. As indicated by some of the local representatives, the MTRM process is perceived

as slow and difficult to rely on for operational needs. One interviewee argues that moving from identified need to implementation “*can take around one year for the budget to be approved, and then followed by several years of research*”. As a result, for some, these processes are more seen as a bonus, rather than the preferred way of creating development based on needs.

5.3.3 Barriers to Double-loop Learning

Double-loop learning is recognized as difficult to achieve in practice, as it requires organizations to go beyond correcting errors and instead actively work with, questioning, and modifying underlying assumptions. This depends on open reflection, effective feedback loops and willingness to change existing ways of working (Auqui-Caceres & Furlan, 2023). The empirical findings indicate that there are several barriers present that could act as limitations to the organization’s ability to create effective double-loop learning. As described in the interviews with the global perspective, there are some tendencies observed of the “*not invented here syndrome*”, mainly in relation to implementation of new technology or process changes developed elsewhere. Relating this to the theories of single-loop and double-loop learning, Auqui-Caceres and Furlan (2023) explain that such behavior can prevent the open reflection needed for double-loop learning to occur, as individuals or groups may avoid questioning assumptions that are considered as the way of working. At the same time, these cultural or behavioral barriers could also be seen to be further reinforced by structural barriers such as time and resource constraints. As indicated in the interviews, important roles for this type of deeper learning, such as MTS and LTS, are often almost fully occupied by daily operations demands, which might limit the time available for long-term development activities. Without this time, there is a risk that short-term problem-solving may be prioritized over exploratory and reflective learning processes. Adding these two factors to each other, there is both a situation where the willingness for implementation in some cases is low, and at the same time the ability to question underlying assumptions is limited, which might have an impact on the overall ability to reach double-loop learning within the organization. However, as important to question back is the actual reason for the defensive routines occurring, as there might be further details not covered by this data collection to explain these tendencies.

Furthermore, the empirical findings indicate knowledge is often stored in silos, either in MTM networks or at the local sites, leading to limited visibility and a lack of structured knowledge mapping across the organization. When knowledge is not easily accessible or shared, it might also have a weakening impact on the feedback loops necessary for organizational learning. As argued by Auqui-Caceres and Furlan (2023), double-loop learning relies on feedback loops to function, and in situations where these are weak or completely missing, the opportunities for deeper learning are reduced.

Another interesting angle identified is the focus on solution identification and implementation. While this acts as a strength for the company in terms of allowing for responsiveness and quick problem-solving, it could also unintentionally narrow the

scope of learning by prioritizing handling situations out of the perspective of “what works”, sometimes over “why it works”. This pattern shares similarities with single-loop learning, where the focus is on correcting errors and restoring performance (Auqui-Caceres & Furlan, 2023). This could be exemplified through the situation with the implementation of Vision Systems, where sites have implemented solutions from external suppliers to quickly address quality or inspection problems. In these situations, the focus has mainly been on developing a solution that works for that site, often including turnkey systems. As a solution itself, it enables fast problem solving, however, it could also limit the deeper learning about how the solution actually functions, why it works well and how it could be adapted or reused across sites both within the same manufacturing area or across different competence areas.

5.4 Balancing Exploration and Exploitation

This section focuses on exploration and exploitation as an analytical perspective for understanding organizational learning. This section is based on March’s (1991) conceptualization of exploration and exploitation, as well as further research on ambidexterity to handle the tension and balance between activities. The concepts are used as an analytical lens to examine how the organization, and specifically the manufacturing technology process, manage the balance between exploration and exploitation in practice.

5.4.1 The Evolving Role of Center of Competence

As argued by March (1991) there is a constant tension for all organizations between developing new knowledge and leveraging existing capabilities, and the organization’s ability to balance between the two activities is of central importance for successful organizational learning (Raisch & Birkinshaw, 2008). The empirical findings show that the Center of Competences (CoCs) have an important, but also evolving role in balancing the tension between exploration and exploitation within the organization related to manufacturing technology development and implementation. As reflected in the empirical data, the CoCs was initially structured to function as a support for the exploratory activities, where CoC representatives describe their role as focusing on “*sharing, creating and exploring new technologies to build new possibilities and encourage innovation*”. This type of focus aligns well with how March (1991) explains the concept of exploration, namely as an activity characterized by experimentation, search, risk taking and the creation of new knowledge or possibilities. In contrast, exploitation is described as having a focus on refinement, efficiency and execution of established solutions.

However, the empirical findings further highlight that the role of the CoCs has gradually become more complex and varies across different technological domains. For example, both the Vision System and the flow visibility CoC seems to have shifted from an exploratory innovation focus towards a more coordination- and exploitation-oriented structure, where the focus seems to be heavily directed towards consolidation of existing solutions and creating support for handling implementation requests

from sites across the organization. In contrast, the CoCs that work with additive manufacturing and intelligent automation have a stronger focus on exploration, in which the leaders from these forums emphasized a focus on early stage development and creation of awareness. When comparing the different technology areas, there seems to be a difference in the level of technological maturity. For both Vision System and flow visibility, the situation today as identified in the interviews, is characterized by several available solutions on the market, both internally and externally developed. In these areas a lot of the focus is on selecting and refining application areas among the different existing alternatives. For additive manufacturing and intelligent automation, the technologies are still at a low maturity level, with no clear or widely implemented solutions in place at the sites. Overviewing these 4 examples and how the work with the CoC is developing within each domain, it seems as though the CoCs might change their focus between exploration and exploitation depending on how well developed the technology is.

Relating this to the theories on ambidexterity, meaning how to balance between exploration and exploitation (Raisch & Birkinshaw, 2008), the CoCs seem to be a type of structure or forum where the focus for exploration and exploitation are redistributed over time. This itself is not a problem, rather as March (1991) explains, a natural cycle as exploration is often costly and uncertain, leading to a tendency of gradually shifting toward exploitation over time. However, in the case with the CoCs this change in focus seems to be mostly emergent, rather than strategically planned for, which might create some sort of uncertainty in expectations across the organization. As further discussed in one of the interviews, there might be a need for additional structures to support the process further. The loosely structured CoC setup may not be enough when reaching a certain technology maturity level, as requirements for coordination and implementation increases over time. This is further evident in the development of the new Computer Vision Business Value Realization (BVR) Network for Vision System, where the new configuration builds on the existing knowledge gathered in the CoC, with the new aim of coordinating to better support scaling, implementation and internal support systems.

5.4.2 Structural Imbalance in Exploration and Exploitation

Simsek et al.(2009) describe contextual ambidexterity as an approach where the same organizational unit keeps a simultaneous focus on both exploration and exploitation. The activities are intended to coexist within the same role and functions without any structural separation. While this enables strong connections to daily operations and needs, it also creates potential challenges as the activities compete for limited resources between short-term efficiency and long-term innovation activities (Gibson & Birkinshaw, 2004; Simsek et al., 2009). As found in the formal descriptions of the roles in the manufacturing technology development processes, both global and local functions across the organization are expected to contribute to both exploration and exploitation activities. In this case there is no strict distinction separating functions into exploratory or exploitative domains when it comes to development and implementation of new technology, instead they are designed to together support innovation, well-functioning practices and continuous develop-

ment. Relating this to the different forms of ambidexterity, this could be similar to how Simsek et al.(2009) explains the concept of contextual ambidexterity.

Going deeper into the empirical findings, there are several examples of how the organization is challenged in terms of balancing resources between the activities, which is mentioned by Simsek et al.(2009) as one of the main challenges. Looking at the work from the local site perspective, interviews highlight how technologies are often introduced when there is a clear problem that needs immediate attention, through statements such as *“we usually start looking for new solutions when there is a problem that is affecting production”*. This tendency reflects a stronger prioritization of exploitation-oriented decisions, as these are better aligned with operational urgency and performance demands. As highlighted in interviews, and consistent with March (1991), exploratory activities are often associated with longer time horizons to see results and higher uncertainty, which may lead to a preference for more immediate, exploitative problem solving. This pattern is also reflected at the network level. Although the MTM structure is created in a way that should enable a simultaneous focus on both exploratory and exploitative activities, the data suggest that many of the key roles in the network tend to be constrained by more daily operational needs or requests. As explained in interviews, the LTS resources are *“often occupied with daily activities, leading to less time to execute and research innovation initiatives”*. This leads to an uneven balance between the two activities. Furthermore, this is also identified in the network overall, where there is a tendency for individuals with an MTS responsibility to be overwhelmed with more problem-solving tasks compared to innovation research. As explained by March (1991), there is a risk for organizations to get stuck in path dependency when focusing too much on exploitation. Keeping a high focus on effectiveness and quick problem solving is a strength, however it needs to be balanced with introducing innovative solutions to stay competitive in the long run. Therefore, managing this balance is of high importance for the organization, as there are indications of unintentionally leaning towards exploitation in the network structures.

Contrasting the balance of activities from the other end, CoC could be found to be a setup which connects stronger to the characteristics of structural ambidexterity. As explained by Simsek et al. (2009), this type of balancing includes that different units focus on either of the activities separately. However, as seen in recent development, there seems to be a gap in transferring the insights developed in the CoCs towards exploitation over time. As found in both the Vision System and flow visibility CoC development, these forums are now reorganized to better support the activities simultaneously within the same unit or forum. As explained by Simsek et al.(2009), for structural ambidexterity to function there is a need for a clear and shared vision allowing the collaboration to connect the activities outside of the units. In this case, there seems to be a gap in this process, where no clear next step is available that can connect the exploratory activities to exploitation later on.

5.4.3 Weak Cross-Functional Connections

Research on organizational learning emphasizes the importance of balancing exploration and exploitation activities to ensure both innovation and operational efficiency (March, 1991; Raisch & Birkinshaw, 2008). Complementing this perspective, Crossan et al. (1999) highlight the importance of well functioning integration mechanisms that allow knowledge to move across levels to coordinate learning processes. Without such integration, organizations risk that such learning may remain fragmented across units. The empirical findings indicate a weak connection between key development functions in the organization, including the CoCs, the MTRM process, and product development activities. Both global and local representatives describe a perceived gap between early-stage technology exploration activities, technology development and product development planning. From a local perspective, statements such as *“it is difficult for the sites to know how to prioritize between different process versus projects related developments as there is a limited visibility of which technologies are planned at early stages and what preparations are required at site level”*, indicates a gap between integration mechanisms. As new product development projects progress rapidly to keep the speed with competitors, technologies are sometimes rushed as part of these projects. This challenge is also reflected in discussions with global representatives. Several interviewees note that many product development initiatives occur outside the CoC and MTRM interface, which results in a weak integration between product development and technology development processes. As many early-stage exploratory decisions related to new product releases are made in the product development teams, there is a high risk of duplication of efforts, or also missed opportunities to integrate new technologies into product releases. As indicated by several of the interviewees, pure product projects are often prioritized over process development projects, and when these operate with limited interaction it may become unclear how development efforts should be prioritized. From an exploration and exploitation perspective, the challenges and insights above could be interpreted as there are several units actively working on exploratory activities in parallel. However, there seems to be a weak alignment and integration between these units and processes.

6

Discussion

This chapter discusses the findings in relation to the broader concept of organizational learning. It highlights key challenges identified and how these could be managed to reduce the duplication of work, with the goal of increasing organizational learning across organizational functions. These insights are then further used to problematize how existing organizational structures, as well as informal practices, both enables and constrains learning, and to discuss potential approaches to strengthen the learning process.

6.1 Organizational Learning Exists but Remains Structurally Fragmented Across Levels

The findings indicate that organizational learning is taking place continuously in the manufacturing technology process. Learning occurs through local problem solving, formal development processes, as well as within CoCs and MTM networks. Overviewing the situation it does not really seem as the organization is lacking learning activities or creation of knowledge. The challenge seems to be more connected to how to transfer, coordinate and integrate these learnings across organizational levels. While knowledge is constantly developed within the organization, it seems to often remain fragmented and siloed, making it difficult to use and share within the wider organizational network.

One clear example of this fragmentation, where initiatives remain isolated within individual factories or MTM networks, while similar solutions are developed in parallel elsewhere in the organization without awareness of existing developments or implementations, is the work with Vision Systems. In this case, several different sites have independently developed and implemented similar technologies, despite facing comparable operational challenge characteristics. This has led to duplicated learning efforts and repeated development work, creating inefficient workflows and unnecessary costs. This suggests that learning is often achieved across the organization, but the translation into broader organizational learning becomes weak. From a 4I perspective, this may indicate breakdowns between integrating (shared understanding across organizational groups and levels) and institutionalizing (embedding knowledge into routines and structures) learning, where knowledge does not become sufficiently included into shared organizational structure and routines.

One interesting aspect to problematize in relation to this fragmentation is whether the organization currently has sufficient structures to support the full organizational learning process, especially in the phases of internalization and institutionalization of learning. While several forums and networks exist for creation, coordination and knowledge sharing, the findings indicate that fewer structures exist that are focused on translating shared knowledge into practical understanding and organizationally embedded learning. This becomes particularly visible when discussing the role of TASC, which is a formally established governance forum with the initial purpose of supporting coordination and alignment of technology development across competence areas. However, the findings indicate that the forum has gradually over time shifted toward more management oriented discussions and external investments questions, while detailed technology discussion increasingly remains within the MTM networks. This raises questions whether there actually are sufficient organizational forums existing to support broader institutionalization of technical learning across competence areas, as the MTM networks do not connect horizontally in the formal establishment of the networks.

The findings further indicate that there seems to be a lack of clear and systematic structures for making knowledge visible and reusable across functional boundaries. Although several formal structures exist, such as the MTM network for capturing knowledge across sites, CoCs for exploration, SharePoint databases to collect and track MTRM initiatives, the findings suggest that these often operate in parallel rather than as integrated parts of a coherent learning system. The findings indicate that there are difficulties in locating existing solutions, identifying important stakeholders and understanding what ongoing initiatives there are in the different sites globally. Even when knowledge within a technology domain exists somewhere within the organization, the information is often fragmented across multiple systems, which in turn makes it difficult to obtain a complete overview of the technology domain. For example, when searching for information about existing solutions, development projects, technology directions or support, there seems to be no single, clearly defined location where the full scope of relevant knowledge can be accessed. This appears to be especially challenging in relation to product development activities, where technology development and implementation often are embedded within product projects rather than being connected to formal manufacturing technology development structures. This may lead to experiences and learning bypassing existing organizational learning forums entirely, which in turn may limit visibility and reuse across the organization.

Another challenge that is important to highlight from the findings is the uneven distribution of learning responsibilities and coordination roles. Variations in how roles such as LTS are prioritized and implemented across sites create inconsistencies in how learning is flowing across levels. When learning becomes dependent on local engagement and available resources, organizational learning risks becoming inconsistent and difficult to coordinate across sites.

In relation to the visibility of knowledge, it can be further interesting to discuss the process specific nature of the MTM networks and how this potentially could also con-

tribute to the fragmentation of learning. Since each MTM network focuses on specific operational domains, knowledge developed within one network may not automatically be interpreted as relevant or applicable for other domains. This may reduce cross-functional learning and reinforce siloed perspectives on technology development and implementation. The challenge therefore does not only concern purely transferring knowledge in a more efficient way, but also how this knowledge is communicated and framed in ways that make it understandable and applicable across different operational contexts.

Changing the perspective, the findings further indicate that there are emerging initiatives that may be a step towards strengthening the organizational learning based on the challenges identified. The BVR network could be seen as one example of this kind of attempt to improve visibility, coordination and transferability of knowledge within the technological domains of Vision Systems. Through mapping already implemented solutions, appointing responsible stakeholders across functional boundaries and creating a shared catalogue of technologies and applications, the network aims to reduce duplicated learning and create one clear pathway for all work related to Vision Systems. An important aspect, which most probably will be successful based on the challenges identified, is that the BVR network is designed to match broader application categories rather than process specific descriptions. As it could be a way of making solutions easier to understand and to relate to across different operational contexts, it could possibly be a way to strengthen organizational learning across competence areas. However, it is important to remember that the findings suggest that the long-term success of initiatives such as the BVR network depends on more than simply collecting and documenting knowledge. It needs to be considered as a continuous process. For such structures to remain valuable, the knowledge needs to remain understandable, applicable and updated over time.

Based on these findings, there are a few interesting aspects that can be discussed as potential actions to strengthen organizational learning. The findings suggest a need for stronger integration between already existing learning structures rather than simply introducing new ones. For example, one important improvement is to explore how clearer pathways could be introduced to support that local initiatives, product development initiatives and MTM networks learning could be combined and transferred into broader organizational processes. The organization may also benefit from clearer ownership of learning responsibilities, such as deciding which forum should be responsible for coordination of existing solutions, and which is more about early stage development. Another important aspect is to oversee possible mechanisms for visibility and reuse of knowledge. Rather than relying on informal interactions and the local networks to function, the organization may benefit from more systematic ways of mapping all knowledge, including everything from already existing solutions to future possible development areas. Furthermore, the organizational learning would probably also be strengthened by focusing on how knowledge is communicated to ensure applicability and understandability, as the knowledge becomes less valuable if there are no possibilities of contextual interpretation of general information. Addressing such improvement may strengthen both the internalization and institutionalization of learning across the organization.

6.2 Informal Networks as Enablers and Constraints for Organizational Learning

One recurring finding from the study is the central role of informal networks and interpersonal relationships in supporting organizational learning within manufacturing technology processes at TTI. Employees frequently rely on personal contacts, experience based relationships and informal communication channels to share knowledge, solve technical problems or to identify relevant stakeholders. These informal interactions appear to be efficient and flexible mechanisms for learning and coordination, particularly in technologically complex environments within the organization.

From the perspective of the SECI model, informal interactions are crucial for the socialization process as it enables tacit knowledge to be shared through direct experience and interpersonal interaction, which is a pattern that is clearly reflected in the findings. These indicate that experienced individuals are able to navigate the organization effectively by using already established relationships either within the active role or from previous networks related to other role descriptions, which enables quick access to further expertise, relevant stakeholders and important operational insights. In many cases, these informal learning pathways appear to be highly responsive and preferred in use for addressing urgent operational issues, operating alongside formal systems for learning such as the MTM network. However, while these informal networks support and enable efficient learning in some cases, the findings also suggest that they can simultaneously act as constraints for broader organizational learning. When knowledge sharing becomes dependent on individuals and their personal networks or relationships, the organizational visibility and accessibility of knowledge may be limited. For new employees or stakeholders who are not yet part of these informal networks, there is a high risk of experiencing difficulties in identifying relevant expertise as important stakeholders may not be clearly pointed out through formal channels, as well as understanding where existing knowledge is located. This creates some sort of uneven access to learning opportunities across the organization.

In order to develop deeper insights and inform possible strategies, it is important to problematize that informal learning networks as the ones across the TTI division may not only reflect cultural preferences, but may also have emerged as a response to limitations in the current formal organizational structures. The empirical findings indicate difficulties in identifying where knowledge is located and who is responsible for specific knowledge domains. Furthermore, formal systems such as the MTM networks, MTRM processes, CoCs and Sharepoint platforms seem to be fragmented in different ways, making knowledge navigation and retrieval challenging. In response to these challenges, informal practices emerge where individuals tend to approach known colleagues or established informal networks to access knowledge more efficiently. This suggests a shift from system-based knowledge search toward relationship-based knowledge accesses. Improvements on structural aspects may therefore support the overall organizational learning process, also in relation to the emergence of informal networks.

Given that these informal practices actually appear effective in addressing and solving urgent operational needs, a relevant question is why such approaches are not simply relied upon as the primary mode of knowledge sharing. While informal networks seem to provide advantages in the organization in terms of speed, accessibility and contextual understanding, the findings also indicate that a strong dependence on these practices leads to structural limitations at the organizational level. When learning becomes dependent on a specific person, the organization may risk becoming vulnerable to turnover and role changes. Knowledge risks getting stuck within individuals or smaller groups instead of being systematically accessible as organizational knowledge. This may be an explanation for the recurrence of duplicated work and repeated learning cycles across the organization, despite the well structured and established formal structures. Another aspect that is important to discuss is that informal networks may also unintentionally reinforce uneven influence and participation across sites and networks over the organizational learning practices. Individuals with stronger relationships, higher visibility in the organization or longer organizational experience may have stronger influence over which knowledge becomes recognized and shared. Based on these findings, the focus for strengthening organizational learning should not be on replacing informal learning networks, rather improving how to include and connect to broader organizational systems and structures.

The organization may benefit from leveraging existing informal practices by using them as input or basis for creating clear visibility of expertise, responsibilities and ongoing initiatives across organizational levels. Since much of these informal networks or relationships seem to already identify “who knows what”, these could perhaps be used and further translated into more visible structures. For example, recurring informal contacts within specific technology areas could be reflected as reference points within broader and formal knowledge sharing networks, even if these are normally outside of the closest network boundaries. This would potentially reduce dependence on prior personal connections and support new employees in identifying value connections and knowledge.

6.3 Balancing Exploration and Exploitation in Organizational Practice

The findings indicate that within the manufacturing technology process networks there is a simultaneous focus and engagement in both exploratory and exploitative learning. From this perspective, the organization demonstrates that there is a clear vision of being able to balance innovation with operational efficiency to achieve competitive advantage. Much of the work is structured in a way that the same role and teams are responsible for both activities at the same time, such as the MTM network acting as support in both development and implementation work. However, the findings further indicate that balancing these activities in practice remains challenging. A reoccurring pattern is that exploitative activities tend to dominate due to reasons such as resource constraints, especially at local site level.

Learning is frequently driven by resolving urgent production needs or performance deviations, which prioritizes short-term responsiveness. While this generally creates operational efficiency it may also limit the opportunities for long-term reflection and learning. One interesting aspect to problematize in relation to this challenge of balancing these types of activities is that this imbalance does not seem to be linked to a lack of interest in innovation within the organization, but rather from structural and operational conditions. Local stakeholders often operate under strong pressure, with both limited time and resources to prioritize exploratory activities. As exploratory learning is associated with uncertainty, longer lead times and less immediate operational value, the engagement may be limited despite ambitions for innovation.

One interesting finding to discuss further is that much of the exploratory activities seems to be disconnected or separated from operational implementation realities. This creates a gap where exploratory learning generates valuable insights and ideas, but lacks pathways toward exploitation and organizational reuse. The changing role of CoCs could be an example that clearly illustrates this challenge. Some CoCs have gradually shifted from exploratory forums toward coordination and implementation support structures as the technology matures. However, as interesting to note is that this shift in focus within the CoC seems to be emergent rather than strategically planned, which may create uncertainties regarding responsibilities, priorities and ownership. To strengthen organizational learning, the organization may therefore benefit from creating clearer structures for how exploratory and exploitative activities should be managed over time. As for now there seems to be challenges in having forums that should support both activities simultaneously. One possible solution could therefore be to separate these activities into two different forums, where one handles exploration and the other handles exploitation. Another possible way of working could be that the CoCs gradually shift focus over time as technologies reach a certain maturity level. However, for such an approach to actually work in practice, the purpose and responsibilities need to be clearly communicated across the organization. Nevertheless the importance lies in clearly communicating what the specific aim of the CoC is and what question should be addressed to these forums. Ensuring these could potentially lead to understanding and sharing knowledge from these forums to the different sites as well as the whole organization more effectively.

Another interesting aspect to highlight, which is not explicitly discussed in theory, is the balance between different units doing exploratory activities. While much of the theory emphasizes the importance of balancing between exploration and exploitation, one could also argue that balancing between different units doing explorative activities is of high importance for increased organizational learning. This could be a highly relevant perspective for this study, as the empirical findings show that even if exploratory activities exist to a relatively large extent, the mechanisms for consolidation of these initiatives are less developed, which may result in hidden implementations and duplication of efforts. This separation could possibly explain why the local sites risk to be reactive in their nature when it comes to technology implementation. The formal structures available to support technological development, such as the MTM network or the MTRM process, appears to be partly decoupled

from other drivers such as new products, which are indicated as high in priority. When these functions operate in separation, it may risk separate roadmaps and priorities, making it less clear on how to align efforts for development projects in general.

6.4 Future Research

Future research on organizational learning should further investigate how existing theoretical models and concepts can be translated and applied into real world settings. While there is much literature on or related to the topic of organizational learning available, these provide limited explanations to how these frameworks or models can be operationalized within complex organizations. A deeper understanding of how to implement models in practice to complement the theoretical understanding could therefore further support organizations in improving how learning is created, shared and embedded.

In addition, as organizations in today's society increasingly move toward digitalization and advanced technology implementation there is a growing need to better understand how organizational learning interacts with these new developments. The findings of this study suggest that existing theories tend to emphasize more individual learning with no clear connection to technology development. Future research could therefore aim to focus on and investigate how individuals and organizations can more effectively capture learning in environments characterized by rapid technological change and increasing digital complexity.

7

Conclusion

The findings of this study show that organizational learning in the manufacturing technology process at TTI is formally intended to work as an integrated and cross-functional system where structures such as the MTM network, center of competences, manufacturing technology roadmap as well as the governance forum TASC should enable organizational learning. However, in practice learning is largely driven by local problem solving at sites, informal networks and different procedures for executing the forums. While the intended structure assumes well functioning mechanisms to support coordination, visibility and integration across the organization the reality shows that these are only partly effective. This leads to a learning system where knowledge is continuously created but inconsistently transferred, internalized and institutionalized across the organization.

The gaps between intended and enacted practices can through this study be explained by the fragmentation in how existing structures work rather than from a lack of learning activities. A number of parallel systems and processes exist to support organizational learning but they are rarely connected and coordinated outside of the closest context. The findings indicate that there are several reasons why the gaps between the intended and enacted practices occur. Aspects such as unclear deliverables from roles and knowledge ownership, limited time at local sites for learning and weak documentation creates structural barriers to achieving organizational learning. Other factors such as the lack of clear ways of how to go from exploratory towards implementation oriented work over time as well as limited integration between different types of projects in the organization further hinders the learning process. This leads to duplicated work, poor visibility of knowledge and limited re-use of existing solutions at sites.

The organization should be aware that there are gaps between the intended and enacted practices and that these insights may support the organization in strengthening organizational learning. The results show that improving organizational learning within the organization is less about developing new structures and more about creating better alignment and coordination between existing ones. Furthermore, clarity regarding roles but also better documentation may enable effective knowledge transfer across the organization. Understanding both the enabling and constraining aspects of both intended and enacted practices may help the organization to benefit from alternative ways of working instead of fully eliminating the enacted practices.

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A

Appendix 1 - Interview Guide (Global Perspective)

- What is your role and how does it connect to new technology development and implementation?
- How do you normally come in contact with new technology? Where does the idea/information normally originate?
- How does your team normally connect with other parts of the organization during implementation/development?
- How do you gather valuable insights regarding the technology that you want to develop or implement?
- What challenges exist in balancing daily production needs with long-term development tasks?
- What are important factors when it comes to information sharing top-down for new technology initiatives to be applicable to the organization?
- Are there any ways in the early stages of technology development to explore if there are similar solutions available within Volvo Group?
- When you learn something important regarding technology, how do you usually share it with others?
- Is there anything that makes it difficult for knowledge to spread effectively in the organization?
- How is ongoing development work documented and shared across the organization?

B

Appendix 2 - Interview Guide (CoC)

- How would you describe the CoC's role in the organization?
- How would you describe the structure and way of working in the CoC?
- When you think about the CoC's responsibilities, do you see them as more operational (sharing, coordinating, standardizing) or more innovative (exploring new solutions, testing ideas)?
- Does the CoC cover the entire technology or subject area needed, or has the focus narrowed to certain specific topics?
- How is knowledge from the CoC spread throughout the organization? Is it clear who is responsible for ensuring knowledge is shared?
- Is the CoC a formal function for knowledge sharing, or does sharing depend on the recipient?
- What would make the CoC more useful/effective for future projects?

C

Appendix 3 - Interview Guide (Local Perspective)

- What is your role and how does it connect to new technology development and implementation?
- How do you normally come in contact with new technology? Where does the idea or information normally originate?
- How does your team normally connect with other parts of the organization during implementation and development?
- What are important factors regarding top-down information sharing for new technology initiatives to be applicable to your factory?
- Are there any ways in the early stages of a technology implementation (idea phase in the factory) to explore whether similar solutions already exist within Volvo Group (e.g., other factories within the same domain or other domains)?
- When you learn something important during an implementation, how do you usually share it with others?
- Is there anything that makes it difficult for knowledge to spread effectively in the organization?
- What kinds of internal support (e.g., forums or networks) were available during the implementation, and how did you make use of them?
- Looking back, was there any support that would have made the implementation or development easier for your team?



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