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# Exploring the Influence of Industry 4.0 Technology on Buyer-supplier Relationships (Supplier Transparency) and Supply Chain Agility

Honey Zimmerman
*University of Missouri-St. Louis*, hmzw5q@umsl.edu

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Honey M. Zimmerman, CPSM, C.P.M.

Master of Business Administration, Western Illinois University, 2004

Bachelor of Business, Western Illinois University, 2002

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George A. Zsidisin, Ph.D., CPSM, C.P.M.
Chairperson

Keith Womer, Ph.D.

Florian Schupp, Ph.D.

## Abstract

Constantly evolving technologies enable supply chains around the world to thrive and become progressively more sophisticated and responsive. Industry 4.0 (I4.0) technologies connect supply chain networks like never before. Still, anecdotal evidence suggests that few firms have implemented such technologies enterprise-wide. Therefore, to investigate the value created from the implementation of such technology, the focus of this study was on buyer-supplier relationships (BSR) and firm supply chain agility (FSCA) in the context of I4.0 technologies. Using mixed methodologies within a single-case study, we set out to answer the research question: Does I4.0 technology influence buyer-supplier relationships and firm supply chain agility, and if so, how? In this exploratory research, data was collected and analyzed in two phases through the use of focus groups and individual interviews (qualitative) and surveys (quantitative) of a single buying firm and its suppliers. The primary purpose of this study was to investigate the effects of I4.0 technology in order to better understand the value of I4.0 adoption. Secondary goals of this study included learning more about information exchange within BSRs (supplier transparency) and FSCA. By maintaining matched dyads during data collection, we gleaned richer insights into perceptions within supply chain relationships. The results from the quantitative analysis in this study reveal that the I4.0 technology had little to no effect on the perceived supplier transparency and FSCA, despite the perceptions expressed in the qualitative phase. However, we found that supplier transparency explains a large portion of the variation in FSCA. This relationship between supplier transparency and FSCA is the most significant contribution of this study and presents opportunities for further research.


*Keywords*: I4.0, Industry 4.0 technology, buyer-supplier relationships, firm supply chain agility, supplier transparency

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# Chapter 1: Introduction

## *Background*

The competitiveness and success of businesses are heavily reliant on information technologies and systems that connect supply chain partners. Without information technology, the level of supply chain integration and collaboration businesses that exist today would not be possible. Information technology allows for complex and large amounts of data to be exchanged among supply chain partners (Vanpoucke et al., 2017). Additionally, it increases visibility throughout the entire supply chain with real-time sharing of information (Prajogo & Olhager, 2012). The alignment of information technology (IT) platforms across supply chain partners is critical to their responsiveness of the changing market environments (Kim et al., 2013).

Continually advancing technologies enable supply chains around the globe to thrive and become progressively more sophisticated and responsive. Many scholars agree that competition exists between supply chains, not individual firms (Ketchen & Hult, 2007; Spekman et al., 1998). Information technology is a major driving force that enables effective and efficient supply chains.

Industry 4.0 (I4.0) technologies—such as the Internet of Things (IoT), artificial intelligence, cloud services, and big data analytics—facilitate greater connectivity and integration within the supply chain and collect and analyze vast amounts of data for improved performance. These technologies enable firms to have flexible manufacturing, improve strategic and operational decision-making, increase productivity, improve efficiency and utilization of resources, and adapt more quickly to changes in the market (Dalenogare et al., 2018; Porter & Heppelmann, 2014). The advantages of I4.0

technologies are classified into three categories: horizontal integration, vertical integration, and end-to-end integration. In this context, horizontal integration refers to the *integration of firms within the supply chain* (e.g., suppliers and customers). Vertical integration is defined as the *integration within a firm* between the organization's different hierarchical levels, functional areas, and business units. End-to-end integration, also called end-to-end engineering, is the overall *integration through the complete value chain of a product*, from product design to post-sale (Dalenogare et al., 2018; Sader et al., 2019). In other words, a considerable advantage of I4.0 is the ability to facilitate integration between many echelons.

### *Statement of the Problem*

Large organizations, in particular, are implementing I4.0 technologies in the current global business environment because of the versatility of applications and the scope of benefits. Some large corporations, such as Coca-Cola, General Electric, Toyota, and Amazon, have been leveraging I4.0 technologies for several years now (Lee, K., 2015). Such sophisticated IT solutions exist to support daily operations, drive operational efficiency, and deliver greater value to the customer at a new level in today's fast-paced business environment (Gates & Bremicker, 2017). However, the problem revealed through anecdotal evidence suggests few companies have implemented I4.0 technologies enterprise wide. Experts agree that the most significant value of I4.0 will be achieved when an end-to-end I4.0 environment is realized. Much of the I4.0 technology adoption is "focused on solving a pain point… [in which] projects tend to be isolated, of limited scope, and driven through functional silos" (Gates & Bremicker, 2017, p. 5). Additionally, small to medium-sized enterprises and firms in emerging countries seem to

face more significant barriers to implement the use of I4.0 and possess lower I4.0 readiness than large companies (Stentoft et al., 2019).

One likely reason more companies have not adopted I4.0 technologies on a grander scale is that the return on investment is neither clear enough to quantify nor is it easy to justify its investment (Gates & Bremicker, 2017). It takes significant resources to implement new technology—not just financial capital, but also human capital—with the time and training required. It is essential to have a clear idea of the potential economic and non-financial returns of such an investment.

This dissertation will focus on non-financial benefits of technology implementation which are often harder to quantify but can significantly impact operational and strategic performance results. In addition to having potential financial implications, reported examples of non-financial benefits of I4.0 include better information, real-time data, improved decision making, superior product or service quality, enhanced responsiveness, increased customer satisfaction, enhanced supplier relationships, and greater collaboration with supply chain partners (Gates & Bremicker, 2017; Lee, K., 2015).

Scholars have studied the relationship between IT and supply chain management, specifically buyer-supplier relationships (BSR), from many different perspectives (Makkonen & Vuori, 2014; Obal & Lancioni, 2013; Pagani & Pardo, 2017; Scherer et al., 2015). Scholars have also studied the importance of relationships among supply chain partners to firm performance across multiple disciplines, including marketing, management, information systems, operations management, and supply chain management (Carr & Pearson, 1999; Heide & John, 1990; Jap, 1999; Swanson et al.,

2018). Most research on this topic has focused on how relational factors (e.g., trust, commitment, communication) contribute to positive outcomes within inter-organizational relationships, such as market responsiveness, operational performance, and agility (Narayanan et al., 2015; Prahinski & Fan, 2007).

With a specific focus on agility, Narayanan et al. (2015) found that collaboration is positively associated with agility performance in a BSR. The impact of collaboration on agility is mediated by trust. Additionally, they found that collaboration positively moderates the effect of trust on agility performance in a BSR. Therefore, we recognized there is a positive association between BSR and agility. However, we did not know if or what influence I4.0 technology has on that association.

Understanding how technology affects business relationships and firm performance is an ongoing process as technology evolves, as will be discussed further in a subsequent chapter. Companies seek to justify significant investments into capital-intensive technology. Stakeholders want to know that there is a return on investment for such technology. The relative novelty of Industry 4.0 means that scholarly research so far has minimally investigated these specific technologies and how they affect business relationships and supply chain agility.

### *Scope of the Research*

This exploratory study examines the results of the posed research question: does Industry 4.0 technology influence buyer-supplier relationships and firm supply chain agility, and if so, how? Firm supply chain agility (FSCA), differentiated from the agility of its extended supply chain, refers to “the capability of the firm, internally, and in conjunction with its key suppliers and customers, to adapt or respond in a speedy manner to a

changing marketplace, contributing to agility of the extended supply chain" (Braunscheidel & Suresh, 2009, p.126).

Using mixed methodology, this case study was conducted in two distinct phases. The first phase, a qualitative approach, consisted of focus groups of mostly procurement professionals from a single purchasing organization and included interviews with individual representatives from its North American suppliers. The purpose of Phase 1 was to explore buyer and supplier perceptions of the BSR, I4.0 technologies currently being utilized in the network, and to explore their perceptions of the influence I4.0 has had on the BSR and supply chain agility, if any. The analysis of the qualitative data informed the hypotheses for the second phase. For the quantitative phase, survey instruments were used to test the ideas. The survey participants included two samples—individuals from multiple locations within the buying firm and supplier representatives. Then we created, tested, and administered the survey instrument and analyzed the data following established protocols and processes.

Industry 4.0 is an emerging area of research, so the primary purpose of this study was to investigate the effects of I4.0 technology to better understand the value of I4.0 adoption. In addition to scholarly contributions in this area, the findings of this study will help managers to make decisions regarding investment into capital-intensive I4.0 technologies and potentially help firms determine with which supply chain partners to make those technological investments alongside. Secondary goals of this study involved learning more about information exchange within buyer-supplier relationships and firm supply chain agility. By maintaining matched dyads during data collection, we were able to glean richer insights into supply chain relationships. Finally, examining firm supply

chain agility, an emerging area of research, has both scholarly and practical impacts. The findings of this study help to fill gaps in the literature about the influence of I4.0 technology on FSCA and the association between information exchange in a BSR and FSCA.

### *Summary*

The following chapters will describe the study in detail. Chapter 2 will review extant literature pertinent to the topics addressed in this study which were used to inform the research. In Chapter 3, the research methodology and the two-phase design of the study will be explained. We will also cover the participants involved, data collection procedures, actions taken to address validity and reliability, and the hypotheses for Phase 2. Next, Chapter 4 reveals the analysis of the data and the results of both phases. Finally, in Chapter 5 an overview will be provided of the entire study, and the results will be discussed, along with the implications for research and practice. We conclude with a discussion of limitations and the possible directions of future research.

# Chapter 2: Literature Review

This chapter reviews prior literature as it pertains to the current study. A brief history of the industrial revolution and an overview of Industry 4.0 is relayed, followed by a review of literature on buyer-supplier relationships and supply chain agility. Related studies are discussed that helped identify gaps in research which led to this dissertation topic.

## *Industry 4.0*

Throughout history, the progression of technology created four major paradigm shifts in manufacturing. The first industrial revolution was the era of mechanical power marked by the discovery of steam power in the 18$^{th}$ century, and the second industrial revolution was characterized by the innovation of mass production and electrical power. The third industrial revolution dawned the era of computerization or the "digital revolution" around the 1970s. We are currently at the beginning of the fourth industrial revolution, often referred to as Industry 4.0, which is differentiated by the integration of information and industrial technologies (Ben-Daya et al., 2019).

For decades, technology has enabled us to exchange information easier, both internally and externally among organizations. Barrett and Konsynski (1982) state, "the interchange of information, whether subtle or concrete, forms the basis of all organizational activity" (p. 93). The first *external* integration system was Electronic Data Interchange (EDI) in the 1960s and 1970s. It significantly changed how organizations conducted business within the supply chain (both upstream and downstream) (Mukhopadhyay et al., 1995). Numerous studies focus on the phenomena surrounding

this external integration (Schubert & Legner, 2011), which has continued to evolve over the years. The internet intensified electronic collaboration with the emergence of e-commerce and e-business applications. Buyers and suppliers worldwide began to share information and conduct transactions electronically (Schubert & Legner, 2011). Additionally, stand-alone supplier relationship management (SRM) applications, as well as customer relationship management (CRM) applications, have further developed to provide higher levels of functionality to manage external relationships (Richey et al., 2010). The evolution of technology is in a constant state of change.

Currently, artificial intelligence (AI), robotics, the Internet of Things (IoT), and data analytics are among the top reported technology trends in the supply chain and logistics industry (Andress, 2020; Pettey, 2019; Robinson, 2020). These technologies are among those that distinguish Industry 4.0. More specifically, Stentoft et al. (2019) proposed 12 technologies that comprise I4.0: big data analytics, autonomous robots, simulation, horizontal and vertical system integration, the internet of things (IoT) (including sensors), cyber-security, the cloud, additive manufacturing, augmented reality, artificial intelligence (AI), mobile technologies, and radio-frequency identification (RFID) and real-time location systems (RTLS) technologies. Definitions for these technologies are in Appendix A. However, Culot et al. (2020) note how there remains ongoing confusion between I4.0 and similar concepts such as digitalization and smart manufacturing. This is, in part, due to a lack of consistency regarding the specific technologies and applications included in I4.0 research. Additionally, the list of technologies is continually growing. There is limited empirical research on these

particular topics as they apply to the management of supply chains (Handfield, 2017), likely due to their novelty.

The basis of I4.0 is the adoption of these technologies to gather and analyze data in real-time, which provides valuable information for decision-making (Frank et al., 2019). According to Frank et al. (2019), Industry 4.0 was first coined in 2011 in Germany as an initiative between their federal government, universities, and private companies to develop advanced production systems.

There are a few primary driving forces behind Industry 4.0: the accelerating growth of data, the greater need for more advanced analysis of this data, the heightened prevalence of human-to-machine and machine-to-machine interactions, and the advancement of industrial technologies such as robotics and additive manufacturing (Sader et al., 2019). There is still much to be learned about the benefits that I4.0 technologies have on firm performance, as well as the adoption and implementation of such technologies (Culot et al., 2020; Frank et al., 2019).

### *Buyer-Supplier Relationships*

Scholars have studied the relationship between buyers and suppliers in great depth, grounded in various theories. For example, researchers have studied BSR through the theoretical lens of relational exchange theory (Zaheer et al., 1998), relational view (Cousins et al., 2008; Whipple et al., 2015), the resource-based view (Jap, 1999; Squire et al., 2009; Whipple et al., 2015), resource dependence (Gassenheimer & Manolis, 2001; Schmitz et al., 2016) and social capital (Autry & Golicic, 2010; Villena et al., 2011). However, the most common theoretical perspectives adopted in BSR research are based on the social exchange theory (Campbell, 1997; Gulati & Nickerson, 2008; Hoffmann et

al., 2010; Nyaga et al., 2010) and transaction cost economics (Autry & Golicic, 2010; Carr & Pearson, 1999; Narayanan et al., 2015; Nyaga et al., 2010; Wagner & Bode, 2014; Zaheer et al., 1998).

Many types and characteristics of BSR have been analyzed according to the literature. Hoque and Rana (2020) grouped BSR typologies from previous research into nine major dimensions: transaction orientation, relational orientation, operational excellence, partnership form, governance pattern, information-exchange mode, cooperative mindset, collaborative attitude, and strategic orientation. The current study included the information-exchange mode dimension as discussed below.

Research also shows that collaborative BSR have extensive benefits. Such benefits include a high level of commitment (Ring & Van de Ven, 1994), loyalty (Chow & Holden, 1997; Prahinski & Fan, 2007), greater integration and information sharing (Wagner & Bode, 2014), market responsiveness (Narayanan et al., 2015), operational performance (Delbufalo, 2012; Prahinski & Fan, 2007), agility (Heric & Singh, 2010; Narayanan et al., 2015), innovation sharing (Wagner & Bode, 2014), synchronization of the supply chain, knowledge exchange (Vanpoucke et al., 2014), positive financial performance (e.g., ROI, sales growth, cash flow) (Delbufalo, 2012), and product and service quality (Carson et al., 2003; Jack & Powers, 2015), many of which have been found to lead to greater competitive advantage (Monczka et al., 1998). This list is not comprehensive, as there is significant research on the benefits of collaborative buyer-supplier relationships. Critical factors in promoting collaborative BSR include, but are not limited to, quality and frequency of communication (Mohr et al., 1996; Mohr & Nevin, 1990; Paulraj et al., 2008), common goals (Wilson, 1995), technological

preparedness (Jack & Powers, 2015), and trust (Bachmann & Inkpen, 2011; Jack & Powers, 2015; Narayanan et al., 2015; Wagner & Bode, 2014).

Information-exchange mode as a dimension of BSR refers to the interaction patterns of organizations (Hoque & Rana, 2020). Information-sharing has been shown to positively impact commitment and trust (Nyaga et al., 2010), and perceived trustworthiness between organizations was correlated to greater information sharing in BSR (Cheng et al., 2008; Dyer & Chu, 2003). Many scholars agree that information exchange facilitates collaboration in BSR, and a collaborative BSR involves the sharing, exchange, or co-development of information, products, and technologies (Dyer & Chu, 2003; Hoque & Rana, 2020; Villena et al., 2011). This research is relevant to our study because I4.0 technologies are also reported to enhance information exchange.

### *Advanced Technology Effects on Relationships*

Relationships within and across organizations of a supply chain facilitate knowledge sharing and integration, which in turn enhances the ability of supply chains to be responsive, agile, and resilient (Kim et al., 2013). Information technology extends enterprises, or as some say they "blur boundaries," it promotes alliances, and directly connects buyer and supplier organizations throughout the supply chain network (Pagani & Pardo, 2017). An organization's technological capability can certainly have a positive effect on collaboration with external partners (Sanders & Premus, 2005).

Technological advancements enable greater collaboration across firms, but we must also consider that buyer-supplier-specific relationships rely heavily on trust and cooperation (Smith et al., 1995; Zaheer et al., 1998). Business relationships are ultimately based on interactions between people within organizations (Gligor & Holcomb, 2013).

Research streams about communication channels inspired the generation of the media richness theory (Daft & Lengel, 1983), the social presence theory (Short et al., 1976), and the theory of media synchronicity (Dennis & Valacich, 1999). Thomas (2013) studied communication channels—specifically, computer meditated communication—in buyer-supplier relationships and found that web-based tools negatively affected new product development because they positively supported knowledge exchange. In a similar manner, this study explored if I4.0 technologies, characterized by connectivity and big data, influence BSR.

An earlier study by Leek et al. (2003) investigated the assumption that moving away from face-to-face interactions, and even audio communication (e.g., telephone), to more email and internet-based exchanges would result in more task-oriented transactions, less compromise, less personal interaction (e.g., E-Commerce), and ultimately, less trust. In turn, it was expected that relationships would become more formal, detached, and challenging to manage. However, the majority of the buyers and suppliers that participated in the study did not agree with the researchers' expectations. Instead, the participants felt the new technology allowed them to form new relationships, create more communication channels and more frequent interactions (albeit more IT-based), and enhance the speed and accuracy of the interactions with supply chain partners (Leek et al., 2003). These findings are significant to the current study since I4.0 technologies allow for increased machine-to-machine communication, reduces the need for human intervention, and lessens human-to-human interaction. Therefore, this study aimed to better understand the perceptions of the technology's impact on relationships between buyers and suppliers.

Previous studies have found that IT alignment is key to successful strategic collaboration between supply chain partners (Kim et al., 2013; Sanders & Premus, 2005; Vanpoucke et al., 2017). Suppliers are also more willing to invest in a relationship, including technology, with a customer firm when trust and communication are present in the BSR (Zhang et al., 2015). Some studies have found that dedicated investments, which are those committed to a relationship with a specific buyer or supplier (Heide & John, 1990), lead to trust (Ganesan, 1994; Palay, 1984). While other studies found that investment does not significantly impact trust in the BSR, they also suggested that suppliers are more likely to commit to relationships with buyers who are engaged in a greater exchange of information (Nyaga et al., 2010). Similarly, research indicates that effective use of technology is an essential criterion for successful BSR collaboration (Jack & Powers, 2015; Ramanathan et al., 2011). This study explored this association further in the context of I4.0 technologies.

### *Supply Chain Agility*

Firm performance is often studied in business research. There are numerous ways scholars measure firm performance. For example, some studies focus on financial performance (e.g., profitability, return on assets, market valuation, etc.). In contrast, others assess the non-financial performance (e.g., operational efficiency, market share, strategic performance, customer satisfaction, etc.). Strategic performance refers to long-term strategic metrics and indicators, such as new product development, improved organizational agility, lean manufacturing implementation, business acquisitions, strategic supply chain partnerships, and growth into new markets. To measure strategic

performance in the current study, we examined the emerging research area of firm supply chain agility, both of the buyer and supplier firms.

Scholarly research on "organizational agility" dates back to the late 1990s within the context of manufacturing; however, studies regarding agility within supply chains did not start until around 2000 (Fayezi et al., 2017). Although some researchers and practitioners use the terms flexibility and agility interchangeably, many scholars have determined that supply chain flexibility and supply chain agility are discrete capabilities (Fayezi et al., 2015; Gligor et al., 2013; Swafford et al., 2006).

Fayezi et al. (2015) define supply chain agility as a *strategic* ability to sense and respond to internal or external uncertainties, whereas supply chain flexibility is more of an *operational* capability to efficiently change in response to those uncertainties. Flexibility is generally related to internal aspects of an organization, whereas agility is related more towards its external aspects (Gligor et al., 2013). Research indicates that supply chain flexibility directly and positively impacts supply chain agility (Swafford et al., 2008). Many scholars suggest that flexibility is an important antecedent of supply chain agility (Braunscheidel & Suresh, 2009; Chan et al., 2017; Swafford et al., 2006). However, Gligor et al. (2013) concluded that flexibility is one of the *dimensions* of supply chain agility. Their multidisciplinary approach found five dimensions of Firm Supply Chain Agility (FSCA): alertness, accessibility, decisiveness, swiftness, and flexibility (Gligor et al., 2013).

Alertness, defined as the ability to quickly detect changes, opportunities, and threats (Gligor et al., 2013), was first posited as a distinct dimension of FSCA by Li et al. (2008). Alertness displays as the prompt recognition of changes in both the direct supply

chain and the surrounding environment, while also discerning emergent market trends and anticipating disruptions (Li et al., 2008). Once an organization is aware of a potential change, it must access relevant, real-time information to proceed with an agile response, which is the second dimension of FSCA, accessibility. The third dimension, decisiveness, is the ability to make decisions with resolve, which includes coming up with potential options, selecting the best option, and responding to the change accordingly. Gligor et al. (2013) posit these three dimensions as the cognitive part of FSCA, whereas the last two dimensions—swiftness and flexibility—are considered the physical dimensions of FSCA. Swiftness is defined as the ability to execute decisions *quickly*, whereas flexibility is the ability to adapt tactics and operations as needed. From their study, Gligor et al. (2013) formed a more comprehensive definition for FSCA, a definition which we also used for our research:

> A firm's supply chain agility is manifested through the firm's cognitive and physical capabilities that enable the firm to quickly detect changes, opportunities, and threats (alertness), access relevant data (accessibility), make resolute decisions on how to act (decisiveness), quickly implement decisions (swiftness), and modify its range of supply chain tactics and operations to the extent needed to implement the firm's strategy (flexibility) (p.102).

We examined the FSCA of both the buyer and supplier organizations instead of the agility of the extended supply chain.

Prior research has found that agility is the central trait of the "best" supply chains (Lee, H., 2004), therefore, the findings in our study regarding FSCA have important practical and theoretical implications. Furthermore, previous studies have found that IT

integration affects supply chain flexibility, resulting in higher supply chain agility which suggests that investing in IT integration with supply chain partners builds agility (Swafford et al., 2008). However, we found no empirical research specific to the influence of I4.0 technologies on the agility of a firm's supply chain.

### *Summary*

This chapter presented a thorough review of the main components of our study: Industry 4.0 technologies, buyer-supplier relationships, and supply chain agility. The extant literature on BSR is extensive, and this was but a glimpse of all that comprises its knowledge base. The investigation of supply chain agility, and even more so of Industry 4.0, has left much to still be explored. By filling gaps in the existing literature, this study makes significant contributions to these growing research areas. The following chapter describes this study's research methods and participants.

# Chapter 3: Research Methodology and Study Design

This chapter presents the methodology selected for this study. We will describe the research design, participants, data collection process, and the details of its validity and reliability for the two distinct phases of the study. We will also discuss the development of the hypotheses for Phase 2 and how these variables were measured.

## *Research Methodology*

Since it is unclear if and how I4.0 technologies influence the association between buyer-supplier relationships (BSR) and agility as described in Chapter 2, our study was exploratory in nature. This study was designed as a single-case study using mixed methods for data collection. Data was collected and analyzed in two phases through interviews and surveys of a single buying firm and a sample of its suppliers. We selected a mixed methodology based on our research question which examines relationships in the context of novel technology for which there is little extant literature.

A single-case study design was selected for this research because of its exploratory nature and due to the embedded units of analysis. A single-case "embedded" design involves units of analysis at more than one level (Yin, 2018). We investigated the influence of Industry 4.0 technology on the focal firm's supply chain agility, so the firm was our unit of analysis. However, we also analyzed the phenomenon in the context of organizational relationships with multiple supplier organizations. The "embedded" units of analysis were the interorganizational relationships.

According to Meyers (2013), case study research is particularly useful when the topic is new, and not a lot is known about it. Meyers (2013) points out the usefulness of

studying a phenomenon with evidence "from real people in real organizations to make an original contribution to knowledge" (p. 76). Case studies can involve either a single case or multiple cases and contain either a singular unit of analysis or numerous units of analysis (Yin, 2018). Multiple-case designs are usually preferred over single-case studies because single-cases are often subject to greater criticism and are vulnerable to skepticism regarding the uniqueness of the case. However, the implementation of the mixed methodology nested in the single-case design strengthened the robustness of the current study. It allowed us to gather multiple sources of evidence and triangulate the data (Yin, 2018). Triangulation provides construct validity within the case study method (Ellram, 1996), which we will discuss in more detail later.

Mixed methodology is not standard in supply chain management research (Tu, 2018), but it was appropriate for this study because we were exploring a relatively novel phenomenon. Using a sequential, mixed approach within the case study, we could uncover more significant insights and strengthen the validity with better, more accurate inferences addressing our research question than we could with either method individually (Venkatesh et al., 2013).

Mixed methodologies leverage the strengths and weaknesses of quantitative and qualitative methods and serve several scholarly research purposes. Venkatesh et al. (2013) compiled a list of goals for mixed methods research adapted from prior research which included: complementarity, completeness, developmental, expansion, corroboration/confirmation, compensation, and diversity. For a mixed approach to be utilized, it should serve one or more of these defined objectives. Out of the seven rationales presented, there were two we utilized for our mixed approach:

complementarity and developmental. Complementarity refers to studies that use mixed methodology "to gain complementary views about the same phenomena or relationships" (Venkatesh et al., 2013, p26). This was a strength for our study. The primary purpose of using the mixed methodology in this study, though, was to serve a developmental intent, wherein one part of the research provides hypotheses that are then tested in the next part of the research (Venkatesh et al., 2013).

Prior to starting the research, we obtained certification through the Collaborative Institutional Training Initiative (CITI) for Social and Behavioral Research. Their training covers the topics of protecting human research participants, the responsible conduct of research, and other ethical considerations regarding privacy, confidentiality, and anonymity. For Phase 1, we took extra precautions to maintain the privacy and confidentiality of the participants. For Phase 2, the primary concern was maintaining anonymity of the survey respondents.

Informed consent was required for all participants. For both phases of the study, informed consent documents were provided to all potential participants prior to starting the data collection. We included information for the participants to make them fully aware of the purpose of the research, what would be expected of them, and the potential harms and benefits of participating in the study. We also included language that relayed that their participation was completely voluntary, and that individuals could withdraw at any point in the study. Additionally, we explained the process for protecting their privacy and confidentiality, which included secure data collection and storage. Copies of the consent documents are in Appendices C, E, and H.

The first phase of this study (referred to as Phase 1 hereinafter) involved qualitative data gathered from a series of focus groups and individual interviews. Upon completing the data analysis from Phase 1, our findings led us into Phase 2, which involved quantitative data gathered from the surveys. The following sections of this chapter describe the participants and procedures for both phases of this sequential, mixed methodology.

### *Phase 1 Qualitative Design*

We used both focus groups and individual interviews for qualitative data collection in the first stage of the study. Focus groups involved gathering information from the participants within the buying organization. Focus groups are particularly suitable for exploratory research when little is known about the phenomenon of interest (Stewart & Shamdasani, 2015). Focus groups can also be helpful to gain shared views on specific topics. Synergy is often created, resulting in a good discussion flow that stimulates participants to share their thoughts and articulate their opinions (Meyers, 2013). Similarly, focus groups are useful for exploring how potential respondents might talk about specific topics, the language they may use, and discovering appropriate scaling approaches for subsequent survey questionnaires (Stewart & Shamdasani, 2015).

Instead of focus groups, we used individual interviews in this phase in order to learn from the key suppliers. Since more than one company was involved from the supplier side and some suppliers may have provided competitive goods or services to the focal firm, we were concerned that confidential and proprietary relationship information could be shared among the suppliers and that the possibility of this could then restrict the participants' openness. Also, since we sought to understand the nature of the different

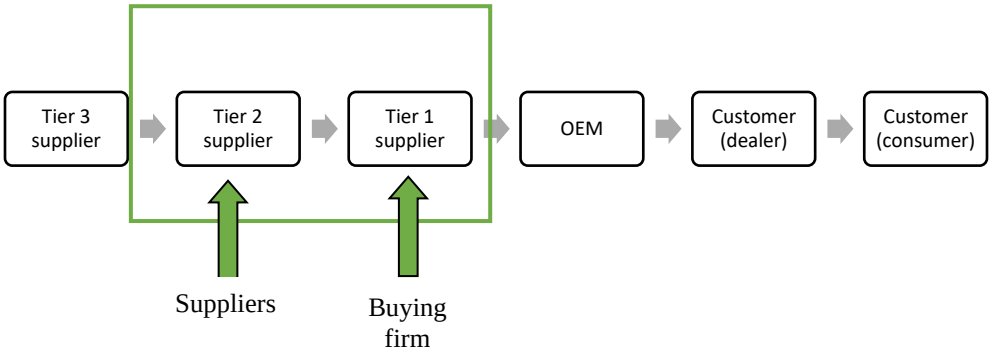
organizational relationships and the suppliers' interactions with the focal firm, focus groups were not appropriate. Individual interviews are the most common technique used for gathering qualitative data in business research and may be the most important technique to gain a 'window' into an organization (Meyers, 2013). The following sections will describe the participants and data collection process for Phase 1 in more detail.

### *Phase 1 Participants*

The participants of this case study (both Phase 1 and Phase 2) included individuals from one buying firm and from several of its suppliers. Figure 1 illustrates where the participants fit into our study within the organization of the overall supply chain of the automotive industry. The purchasing firm was a global tier-one supplier to the automotive and industrial sectors. From an OEM perspective, the suppliers in this study were considered tier-two suppliers within the overall automotive supply chain.

**Figure 1**

*Where Study Participants fit into the Organization of the Automotive Supply Chain*




The focal firm (purchasing organization) was a large corporation with 77 manufacturing plants in 22 countries (170 locations, including research and development centers, sales and service networks, and production facilities) that employed nearly 90,000 people worldwide. In 2019, the company reported revenues close to 14.5 billion euros. In Phase 1, we initially focused on the firm's Americas region, which includes both North and South America, and made up 21.9 percent of the firm's total revenues in 2019.

Phase 1 of the study consisted of two focus groups from the buying firm. Fourteen participants total (six and eight in the two groups respectively) of varying levels within the firm participated from four different facilities in the U.S. and one facility in Mexico. The individuals' length of time with the organization ranged from a minimum of 6.5 years to a maximum of 47 years. The average length of time with the company was 16 years across all 14 participants. The participants' length of time in their respective roles ranged from two months to six years. Although the focus groups primarily consisted of

sourcing and procurement professionals (8, 57%), we also included professionals from other roles in Phase 1: one scheduler, two logistics managers, one cost engineer, and two customer account representatives. All focus group participants except one had either previous or current direct interactions with suppliers. The customer account representatives did not work directly with suppliers at the time of the study but instead managed relationships on the customer side. They were able to share a unique perspective that helped paint a more complete picture of the technology and supply chain interactions related to this study.

In Phase 1, we also conducted individual interviews with three suppliers. The supplier participants all represented "key suppliers," which we defined as suppliers, direct or indirect, who were perceived as strategic to the operations and success of the buying organization. Although more interviews are often desirable for in-depth case studies, it is possible to base case study research entirely on a few key interviews (Meyers, 2013; Yin, 2018). For the current study, since the primary purpose of Phase 1 was to inform Phase 2, three interviews were considered sufficient to better understand the types of I4.0 technologies used in the interactions within the supply network and whether they influenced the relationships and the agility of the supply chain. The three supplier firms were chosen based on the initial criteria established; they were required to be considered a key supplier (as previously defined), in the top 40 North American (N.A.) suppliers by purchase volume, and have direct interactions with the facility locations involved in the focus groups. They were classified as N.A. suppliers because they have operations in North America, but their country of ownership was not specified. Additionally, all of the top 40 N.A. suppliers by purchase volume happened to be small to

medium-sized enterprises with 500 or fewer employees with annual revenues less than $300 million. The participants interviewed consisted of two sales managers and one general manager, all with direct contact and working relationships with the buying organization.

### *Phase 1 Data Collection Procedures*

Qualitative data was gathered in the first phase of the research. Through interviews, both individual and focus groups, we sought to better understand the specific I4.0 technologies in use and gather information regarding the participants' perceptions of how these technologies influenced buyer-supplier relationships and supply chain agility.

We conducted a pilot test for the group and individual interview questions before the start of Phase 1. The interview questions were pre-tested on four individuals: two academic professionals and two practitioners. Both academic professionals taught in supply chain management programs within AACSB colleges of businesses in the United States. Both individuals had prior supply chain experience in the field, managing buyer-supplier relationships (one in procurement and one in sales). The two practitioners selected for the pilot test also had experience with managing buyer-supplier relationships. One was a senior-level buyer and the other was a senior-level sales manager with customer relationship responsibilities in the technology sector. The expert knowledge about I4.0 technologies offered by this individual was an added advantage in providing feedback regarding the technical aspects of the interview questions. We made minor wording modifications to the interview questions based on their input.

All focus groups and individual interviews in the qualitative phase were conducted remotely with secure video conferencing software over the internet, using a

combination of Microsoft Teams and Zoom depending on the respondent's preference. Most online interviews recorded in previous literature have been carried out in an asynchronous manner (such as email). Online focus groups, which became popular in the late 1990s, were conducted asynchronously with online bulletin boards and discussion groups (Hooley et al., 2012). Even in the late 2000s, online interviews were considered relatively novel. Today's technology is faster, more available, user-friendly, and maybe most importantly, it has become familiar to a much larger audience than ever before. Today, researchers frequently utilize video conferencing in order to reduce costs, reach a more extensive and diverse audience, and reduce the time required to conduct interviews, thus eliminating the need for travel (Gray et al., 2020).

Employing video conferencing technology for the interviews allowed us to gather an expanded pool of potential participants and allowed for scheduling flexibility. Some experts suggest that the more informal nature of virtual platforms results in richer participation and greater openness in comparison to traditional face-to-face interviews (Stewart & Shamdasani, 2015). Utilizing webcams for interviews makes the interactions between participants comparable to a face-to-face interview. Even though body language is impeded when utilizing video conferencing software, by being able to view each other's facial movements, nonverbal and social cues still remain (Janghorban et al., 2014). Although interacting by means of a webcam for an interview may negatively affect the feeling of closeness or intimacy, resulting in diminished spontaneity and openness of dialogue (Stewart & Shamdasani, 2015), when comparing the online conferencing interviews to face-to-face interviews, researchers have found no difference in the quality of the interviews (Gray et al., 2020).

In Phase 1, we began with the focus groups of individuals from varying levels and roles within the buying organization from multiple North American locations. Working with the buying firm's Vice President of Purchasing & Supplier Management for the Americas region, we identified focus group participants from multiple facilities in North America. We sent an introductory email (included in Appendix B) requesting their participation and providing sample questions, along with two attachments, the consent documentation (Appendix C) and a list of I4.0 technologies (Appendix A).

With the use of focus groups, it is generally recommended to hold at least three sets of interviews with different groups of people on the same topic to identify common themes (Meyers, 2013; Stewart & Shamdasani, 2015). However, Stewart & Shamdasani (2015) state that one or two focus groups may be sufficient if the population of interest is relatively homogeneous. We found that two focus groups were adequate for Phase 1 of this case study due to the similarity of the population we were seeking to study, which consisted of personnel from one company in procurement-related roles who interacted with suppliers.

During the respective focus groups, we centered our conversation on six open-ended questions as outlined in the interview protocol (included in Appendix F) and kept the group discussion to one hour, as suggested by Meyers (2013). At the beginning of the focus group discussion, we asked the participants to write down keywords for their initial responses to each question posed before starting the open discussion. Then, as the conversation naturally slowed down, we asked if anyone wrote down something that was not already discussed. This was helpful to minimize groupthink and increased the likelihood that all responses were recorded.

The group format proved valuable for engaging in thoughtful discussion, and participants effectively interacted with one another to provide thorough responses. Based on the comments and energy within the focus groups, we suspected this format resulted in more complete results than we would have gotten in individual interviews. For example, when discussing the technology used, the synergy among participants was evident by their comments, such as, “Oh yeah, I forgot about that,” and “That makes me think of another platform I use a lot” Upon completion of each focus group, we sent the audio recording to a secure third-party transcription service.

The second part of the qualitative phase involved interviews with individual representatives from key suppliers. Together, with the buyer’s management team, we selected three suppliers that worked directly with the N.A. facilities represented in the earlier focus groups. Similar to our interactions with the focus groups, we reached out to each supplier representative with an introductory email that included sample questions (Appendix D), the consent documentation (Appendix E), and a list of I4.0 technologies (Appendix A).

We used semi-structured interviews to cover the same topics in each interview while encouraging participants to respond openly and discuss their experiences and perceptions regarding the issues (Corbin & Strauss, 2015). We started with five main questions and continued with the alternate questions when appropriate; however, most of the participants already addressed the majority of the alternate questions in their open-ended responses to the initial questions. All interviews were limited to a maximum of one hour. The interview protocol for the supplier firms can be found in Appendix G. Upon

completing each interview, we sent the audio recording to a secure third-party transcription service provider.

### *Phase 1 Validity and Reliability*

Good research design requires particular attention is given to validity and reliability. As mentioned earlier, employing mixed methodology nested in a single-case study added to the robustness of this study, which had an exploratory objective. The sequential, mixed approach within the case study enabled us to uncover more significant insights and strengthen the validity with better, more accurate inferences that addressed our research question than we could have accomplished with either method individually (Venkatesh et al., 2013). In the qualitative phase, we focused specifically on external validity, construct validity, and reliability. Internal validity does not pertain to exploratory studies since we are not attempting to explain or establish a causal relationship (Yin, 2018).

External validity in a case study starts with the form of the research question and is addressed during research design (Ellram, 1996; Yin, 2018). The research question for this study focused on *how* Industry 4.0 technology influences buyer-supplier relationships and firm supply chain agility. Therefore, the structure of our question helped in seeking generalizations of the results (Yin, 2018). External validity was further pursued by selecting a “typical” case or one representative of a large number of other cases (Shanks & Parr, 2003; Yin, 2018). Most importantly, in a single-case study such as this, external validity is dependent on using theory to establish generalizability of the results as opposed to a multiple-case study that relies on replication logic (Ellram, 1996; Yin, 2018). Gaya & Smith (2016) reiterate the idea that in single-case studies existing

literature provides a rich theoretical framework for the research design, which is necessary for external validity. Although this research was exploratory and took an inductive approach to build upon theory, during the research design, we relied on existing theory to establish the research protocol which allowed us to generalize the results beyond this single case. External validity is important because it reflects the level of accuracy of the results in representing the phenomenon studied (Ellram, 1996). Further discussion on the generalizability of the results can be found in Chapter 5.

Construct validity is addressed chiefly during data collection (and some during composition) and focuses on recognizing appropriate operational measures for the studied concepts. Three primary tactics were implemented in the current study to address construct validity: using multiple sources of evidence, establishing a chain of evidence, and having key informants review the overall case study (Ellram, 1996; Yin, 2018). First, we gathered data from multiple sources through two focus groups of buyers and three supplier interviews, allowing us to triangulate the qualitative data collected. Data gathered involving multiple informants strengthens the construct validity (Ellram, 1996). Additionally, later in phase two, we gathered quantitative survey data from a larger sample of buyers and suppliers to further corroborate the evidence, allowing us to present multiple indicators, strengthening our study's reliability (Yin, 2018). Secondly, we intentionally established a logical flow or “chain” of evidence so the path, from initial research question to ultimate findings, could easily be followed (Ellram, 1996; Yin, 2018). This process, discussed further in Chapter 4, enabled us to identify operational measures that matched constructs from published research (Yin, 2018). Finally, two focus group participants from the focal firm and one supplier interviewee reviewed respective

portions of the draft report to support construct validity. Yin (2018) reports how this procedure boosts the overall quality of the case study because it corroborates the essential findings and evidence presented, and enhances the accuracy, resulting in greater construct validity.

The third quality test, reliability, addresses the repeatability of the study to achieve the same findings and conclusions. A common tactic for addressing reliability in case study research is providing case study protocol (Ellram, 1996). Case study protocol is essential in multiple-case studies because protocol needs to be established for each case within the multiple cases. However, in this single-case study, we maintained a chain of evidence by documenting in detail all procedures that were followed so it could be easily replicated (Yin, 2018). In addition to the content of this chapter (Chapter 3), additional supporting documents are provided in the appendices—including the initial correspondence with participants, informed consent forms, and interview guides—so this study could easily be replicated. Table 1 presents a summary of each test conducted, created to ensure quality and record the tactics employed in this research.

**Table 1**

*Phase 1 Tests for Validity and Reliability*

| Test | Description | Tactics | Implementation | Stage in which tactic is addressed |
|---|---|---|---|---|
| External Validity | Establishes generalizability of results | a) Forming the research question with "how" or "why" | a) Explore "how" for the research question. | Research design |
| | | b) Using theory in a single-case study | b) Rely on theory to establish research protocol. | |
| | | c) Selecting a "typical" case | c) Select a case that is representative of a large number of other cases. | |
| Construct Validity | Identifies correct operational measures | a) Triangulating data from multiple sources | a) Gather qualitative data (from interviews with three suppliers and two focus groups of buyers) AND quantitative data survey data from a larger sample of buyers & suppliers. | Data collection & composition |
| | | b) Establishing a chain of events | b) Establish a clear, logical flow of evidence from start to finish. | |
| | | c) Having key informants review the case study research | c) Review the draft by two members of the focus group from the focal firm | |
| Reliability | Addresses repeatability, with the same results | a) Maintaining chain of evidence | a) Maintain the logical flow of evidence from start to finish with detailed documentation | Data collection |

### *Phase 2 Quantitative Design*

For the second phase of the study, the research question remained our focus, and we narrowed the scope to stay within the three original topics (I4.0 technology, BSR, and FSCA). Based on the initial findings from Phase 1, detailed in Chapter 4, Phase 2 focused solely on the *how* aspect of our research question. After reviewing the extant literature surrounding the newly narrowed scope of our investigation, we developed hypotheses and tested them utilizing survey instruments for a quantitative examination. The following sections will describe Phase 2 in detail.

### *Phase 2 Hypotheses Development*

Transparency was a major theme that emerged from Phase 1, as detailed in Chapter 4. The emphasis on transparency by the participants was unexpected, so we decided to explore it in greater depth for the study's second phase. Specifically, regarding the buyer-supplier relationship (BSR) in Phase 2, we limited our investigation to the BSR dimension of information-exchange mode (Hoque & Rana, 2020) by focusing on supplier transparency.

Key concepts, such as visibility and traceability, are often used near synonymously with transparency in existing literature (Montecchi et al., 2021). Morgan et al. (2018) frame visibility and traceability as two dimensions of supplier transparency. Meanwhile, other scholars conceptualize visibility and traceability as enablers of transparency (Carter & Rogers, 2008). Transparency refers to the ability to “see-through” information that typically may not otherwise be shared between two supply chain

partners (Lamming et al., 2001). Hultman and Axelsson (2007) found that trust, transparency, and utilization of information technology are largely interrelated.

Morgan et al. (2018) assert that supply chain transparency is a requirement for conducting business today. Advances in information technology applications in supply chain activities, and specifically the growth in the application of emerging transparency technologies (such as RFID, IoT, blockchain, etc.), has intensified the interest of transparency within buyer-supplier relationships for both practitioners and scholars (Hultman & Axelsson, 2007; Montecchi et al., 2021). Organizations may desire greater transparency within their supply chains for numerous reasons—visibility for enhanced quality and sustainability, operational efficiency, regulatory compliance, and safety assurance (Hultman & Axelsson, 2007; Montecchi et al., 2021). Furthermore, the Covid-19 global pandemic has also made evident the need for greater visibility and transparency within the supply chain (Finkenstadt & Handfield, 2021; Montecchi et al., 2021).

In the current study, both the supplier interviewees and the focus group participants in Phase 1 perceived transparency as a benefit of I4.0 technology. Similarly, existing literature suggests technology is an enabler of supplier transparency (Hultman & Axelsson, 2007; Montecchi et al., 2021; Morgan et al., 2018). In 2011, Brown et al. reported that companies were already integrating big data to create "a world of radical transparency," stating, "they are integrating data from multiple systems, inviting collaboration among formerly walled-off functional units, and even seeking information from external suppliers and customers to co-create products" (p. 27). This led us to our first hypothesis:

*H1. Supplier transparency is positively related to I4.0 technology implementation.*

One of the most critical enablers of supply chain agility is information sharing and communication (Gligor & Holcomb, 2012). Indeed, many scholars agree that communication is a key enabler of agility (Jain et al., 2008; Lin et al., 2006; Van Hoek et al., 2001). Furthermore, technology integration is vital in achieving formal communication. Advances in technology have facilitated the flow of information among supply chain partners (Gligor & Holcomb, 2012). Extant literature consistently supports that information technology positively impacts supply chain agility (Bottani, 2010; Power et al., 2001; Swafford et al., 2008). DeGroote et al. (2013) found that IT improves the quality of information (adequacy, accessibility, accuracy, and timeliness) and found strong support that IT increases supply chain agility. Therefore, we proposed the following for our second hypothesis:

*H2. I4.0 technology implementation is positively related to firm supply chain agility.*

The perception of many Phase 1 participants in the current study was that transparency contributed to the agility of a supply chain, as described in Chapter 4. Scholars have found that information sharing results from transparency between organizations. Supplier transparency allows organizations to share demand fluctuations and forecasts, reducing demand distortion (Morgan et al., 2018), which we proposed ultimately impacts FSCA. Additionally, Hultman and Axelsson (2007) found that focusing on supply transparency by sharing information about material flow increased

flexibility and speed, and decreased inventory costs. Thus, we proposed our third hypothesis:

*H3. Supplier transparency is positively related to firm supply chain agility.*

### *Phase 2 Variable Measurement*

There were three primary constructs in Phase 2: supplier transparency, I4.0 technology implementation, and firm supply chain agility. We used summative response scales (e.g., Likert scales) from prior research for each construct to test the hypotheses.

We utilized the survey instrument established and validated by Morgan et al. (2018) for measuring supplier transparency. Their research resulted in a two-dimensional supplier transparency construct that focuses on stakeholder visibility and supplier traceability. We made only slight wording modifications to the two-factor, 15-item scale. The original wording for supplier traceability items began, “Our major suppliers”, which we changed to, “This supplier” since we asked the buyer participants to complete the survey with a specific supplier in mind. For the supplier survey, we changed the wording to say “Our firm,” allowing us to examine both the buyer perception of supplier transparency and the supplier perspective within the matched dyads (Morgan et al., 2018). We utilized a 7-point Likert Scale from 1 (Strongly Agree) to 7 (Strongly Disagree) for the supplier transparency construct. The complete surveys can be found in Appendices D and E.

The significant emphasis made by the Phase 1 participants on data, in relationship to the technologies they discussed, led us to narrow our investigation regarding I4.0 technology implementation. For Phase 2, we then focused on four technologies: big data,

data analytics, the cloud, and the Internet of Things (IoT). In our study, big data referred to technology used to collect many types of data, such as traditional enterprise data, machine-generated/sensor data, and social data (Opresnik & Taisch, 2015). Data analytics are the specific technological tools used to analyze big data, which involves its storage, management, analysis, and visualization (Russom, 2011). The cloud, or cloud services, refers to servers accessed over the internet, as well as the software and databases that run on those servers (Cloudflare, n.d.). Lastly, the Internet of Things (IoT) is "a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-machine interaction" (Gillis, 2021, para 1).

These four technologies are what Frank et al. (2019) refer to as "base technologies" for I4.0 because they provide the underlying intelligence and connectivity for more advanced I4.0 technologies. The layer of base technologies "enable the Industry 4.0 concept" (p.16). Therefore, we presumed that the greater the presence of these four I4.0 technologies, the more likely the organization was to currently have other I4.0 technologies or plan to have them in the future.

To measure I4.0 technology implementation in our study, we first asked respondents if their company had adopted at least one of the four technologies. If the response was yes, then we adapted the scale from Frank et al. (2019), which suggests asking about the current level of implementation for each of the four technologies on a scale from 1 (not yet implemented) to 5 (advanced implementation). If the response was no, then we adapted the scale from Yu & Schweisfurth (2020), which asked them to

indicate the extent to which their organization planned to implement each of the four technologies on a scale from 1 (no plans to implement) to 5 (already implemented).

The third variable in our study was the supply chain agility of the firm. As mentioned in earlier chapters, firm supply chain agility was differentiated from the agility of the extended supply chain in that we focused on the firm's capability. We assessed the firm's ability to quickly change or respond to changes in the marketplace along with their key suppliers and customers (Braunscheidel & Suresh, 2009). To measure FSCA, we utilized the Gligor et al. (2013) scale, which measures five dimensions: alertness, accessibility, decisiveness, swiftness, and flexibility. The scale for FSCA includes 14 items in total, with three items for each dimension, except accessibility which only has two items. We made only minor wording modifications to the previously validated scale. We used a 5-point Likert Scale from 1 (Strongly Agree) to 7 (Strongly Disagree) for the FSCA construct. The completed questionnaires can be found in Appendices D and E.

For Phase 2 of this study, we captured additional information regarding firm size (based on the number of employees), industry(s) served, country of operation, and length of time in the relationship. Research shows a relationship between a firm size and their technology adoption. Frank et al. (2019) found a correlation between large companies and advanced I4.0 implementation, whereas small to medium-size enterprises (SMEs) lag in the adoption and implementation of I4.0 technologies in comparison (Stentoft et al., 2019; Yu & Schweisfurth, 2020). Additionally, we examined if differences in means existed based on industry(s) served, location, and length of time in the relationship.

### *Phase 2 Participants*

Phase 2 involved conducting surveys of two sample groups—buyers and suppliers. Overall, our final dataset consisted of 100 complete and usable buyer responses, 47 additional buyer responses to be used only for the matched analysis of supplier transparency, 64 finished and usable supplier responses, and 53 usable dyadic matches.

Similar to Phase 1, the individual participants representing the buying firm were from varying levels and roles within the purchasing organization of the focal firm. The sample consisted of 76.4 percent procurement/supply management/sourcing professionals, 14.6 percent supplier development/supplier relationship management professionals, and nine percent self-categorized as other. Seventy-four percent of the buyer respondents had worked for the focal firm for ten years or less. The full breakdown of this sample is illustrated in Table 2. Unlike Phase 1, the sample included representatives from various locations around the world. We expanded the scope beyond North America based on the participant comments in Phase 1 about differences in technology implementation and integration across locations. The responses by region included 32 percent from the Americas, 20 percent from Europe, and 48 percent from other as outlined in Table 2. The Americas region included both North America and South America. Based on the correspondence from management to the purchasing groups, we assumed the “other” category consisted overwhelmingly of personnel from the firm’s Greater China region, but we could not definitively conclude this. All survey participants had direct contact and a working relationship with at least one supplier.

**Table 2**

*Phase 2 Buyer Sample Demographics*

| *N = 100* | Frequency | Valid Percentage |
|---|---|---|
| Role in Organization | | |
| Procurement/supply management/sourcing | 68 | 76.4 |
| Supplier development/supplier relationship mgt | 13 | 14.6 |
| Other | 8 | 9 |
| Missing | 11 | |
| Time with organization | | |
| Less than 2 years | 7 | 7 |
| 2 to 5 years | 35 | 35 |
| 6 to 10 years | 32 | 32 |
| 11 to 15 years | 5 | 5 |
| 16 years or more | 21 | 21 |
| Region of Operation | | |
| Europe | 20 | 20 |
| Americas | 32 | 32 |
| Other | 48 | 48 |

To provide a richer analysis of the buyer-supplier relationships in our study, we set out to evaluate both parties' perceptions of supplier transparency by collecting matched sets of buyer-supplier data. To maintain the matched dyads for the survey, we relied on referrals from the buyer respondents for the suppliers. We asked the survey participants from the purchasing organization to focus on a particular supplier relationship when responding to the portion of the survey that asks about supplier transparency (precisely the traceability dimension), which consisted of eight questions.

Upon completion of the survey, we asked the buyer to send a unique code, the supplier survey link, and a short message to the representative from that supplier, requesting their participation. This portion of the survey can be found in Figure 4. Therefore, the participants in Phase 2 from the supplier side were directly referred by the buyers, allowing us to match the responses. We will cover this process in more detail in the subsequent section about the data collection procedure. We did not specify criteria for the supplier firms beyond that they must be considered a "key supplier," which we defined as those perceived to be strategic to the operations of the buying organization.

The supplier sample consisted of 64 representatives, consisting mostly of sales managers (58.7%) and customer service/account representatives (22.2%). The length of time in a supplier relationship with the focal firm ranged from one to 50 years. Fifty percent of the supplier organizations had worked with the buying firm for ten years or less, and 40.6 percent had maintained relationships with the buying firm for 16 years or more. The full breakdown of the characteristics of the supplier sample is provided in Table 3.

For the supplier sample, we captured details on the location, size, and industries served. For the location, we asked about the respondents' location of operation and the company's home country (country of ownership). Approximately 38 percent of respondents came from operations in the Americas region, 23 percent from Europe, and 39 percent were listed as other. The home country of the supplier firms, categorized in the same way, was 23 percent, 30 percent, and 47 percent, respectively. Of the 47 percent classified as "other," half of those were Chinese firms. The detailed breakdowns of the location information can be found in Table 3.

Fifty-eight percent of the supplier firms had less than 500 employees, and 47 percent of the supplier companies were subsidiaries of a larger parent company. Regarding industries served, in addition to the automotive industry, 60 percent of the suppliers also served industrial markets. Other industries served by the supplier firms included energy (29%), consumer goods (22%), healthcare (18%), and aerospace (18%), as shown in Table 3.

**Table 3**

*Phase 2 Supplier Sample Demographics*

| *N = 64* | Frequency | Valid Percentage |
|---|---|---|
| Role in Organization | | |
| Customer service/account representative | 14 | 22.22 |
| Sales managers | 37 | 58.73 |
| General managers | 6 | 9.5 |
| Other | 6 | 9.5 |
| Missing | 1 | |
| Time in Relationship with focal firm | | |
| Less than 2 years | 1 | 1.6 |
| 2 to 5 years | 9 | 14.1 |
| 6 to 10 years | 22 | 34.3 |
| 11 to 15 years | 6 | 9.4 |
| 16 years or more | 26 | 40.6 |
| Region of Operation | | |
| Europe | 15 | 23.4 |
| Americas | 24 | 37.5 |
| Other | 25 | 39.1 |
| Region of Ownership | | |
| Europe | 19 | 29.7 |
| Americas | 15 | 23.4 |
| Other | | |
| China | 14 | 21.9 |
| South Korea | 6 | 9.4 |
| Japan | 5 | 7.8 |

| *N = 64* | Frequency | Valid Percentage |
|---|---|---|
| Singapore | 2 | 3.1 |
| India | 2 | 3.1 |
| Taiwan | 1 | 1.6 |
| Size of firm | | |
| Less than 50 | 10 | 15.6 |
| Less than 250 | 16 | 25 |
| Less than 500 | 11 | 17.2 |
| Less than 1000 | 12 | 18.8 |
| 1000+ | 15 | 23.4 |
| Industries served [a] | | |
| Automotive | 63 | 98.4 |
| Industrial | 37 | 57.8 |
| Energy | 18 | 28.1 |
| Consumer Goods | 13 | 20.3 |
| Aerospace | 12 | 18.8 |
| Healthcare | 10 | 15.6 |
| IT/Telecommunications | 6 | 9.4 |
| Other | 4 | 6.3 |
| Subsidiary of a larger parent company | 30 | 46.9 |
| Size of parent company [b] | | |
| Less than 5,000 | 17 | 56.7 |
| 5,000 to 10,000 | 6 | 20 |
| More than 10,000 | 7 | 23.3 |

[a] Respondents were allowed to select multiple industries served. The valid percent was the percent of the total respondents that indicted that particular industry. [b] Valid percent for the size of the parent company only included the 30 firms that indicated subsidiary positions.

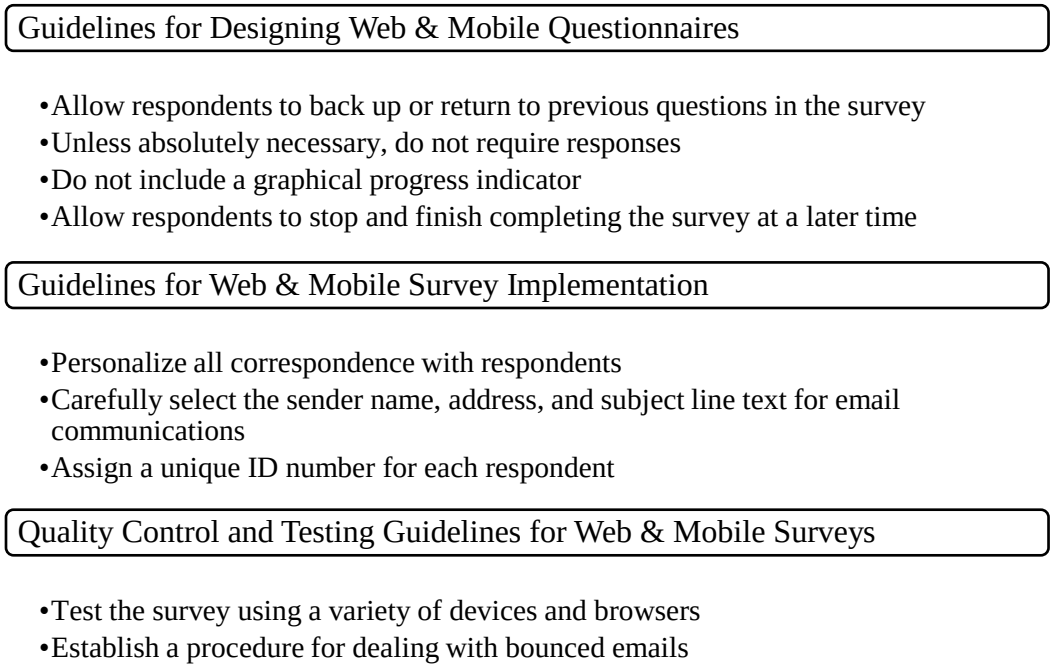
### *Phase 2 Data Collection Procedures*

The questionnaires—created and administered electronically through Qualtrics, a secure survey software—followed established protocol and processes for creating, testing, and administering the survey instrument. In designing the survey questionnaires, we utilized the guidelines set out by Dillman et al. (2014, pp. 349-350) for web-based

surveys. A sample of the specific guidelines used in this study is outlined in Figure 2 and includes recommendations for designing, implementing, and testing web and mobile surveys.

**Figure 2**

*Guidelines for Web-Based Surveys*

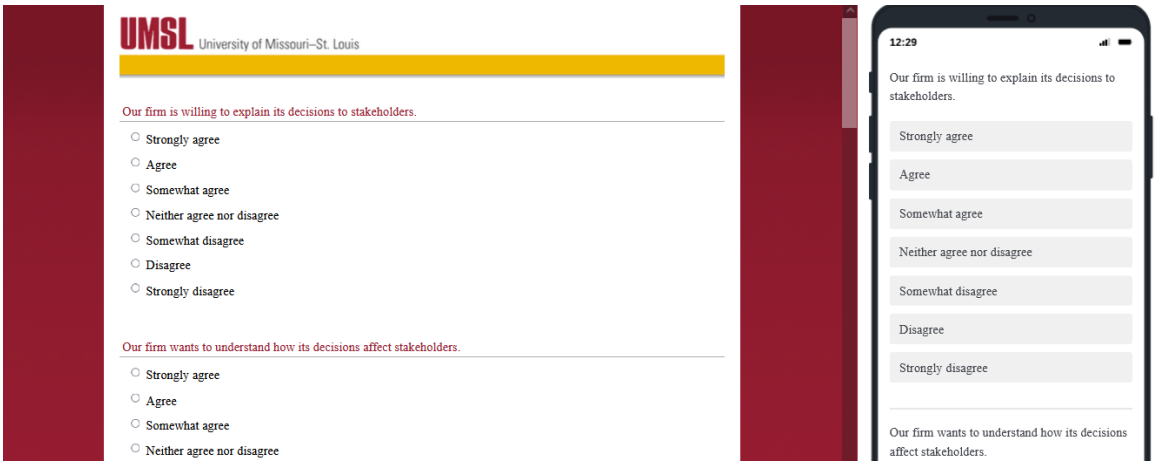



Although the survey questions themselves were from previously established measurement instruments, significant effort went into the design of the questionnaire to improve their quality. In self-administered surveys, such as this study, good visual design can minimize item nonresponse and measurement error, help respondents process the survey, and make it more appealing and efficient (Dillman et al., 2014). Additionally, we paid particular attention to ease of use and the burden on the respondent. We spent

significant time ensuring the survey was optimized for both personal computers and mobile devices, such as smartphones and tablets, as shown in Figure 3.

**Figure 3**

*Survey Appearance for Computer versus Mobile Device*



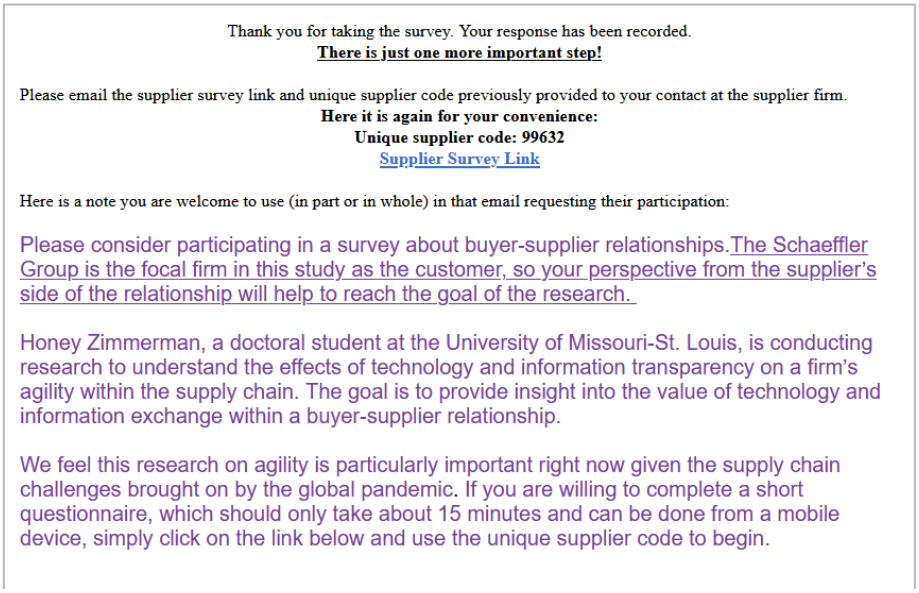

Before distributing the survey, we collaborated with the management team and the workers' council to ensure anonymity and strengthen the language regarding volunteer participation. Minor adjustments were made to the survey, such as minimizing open-ended questions and removing unnecessary demographic information regarding the individual respondent. Since our focus was at the organizational level, we did not ask any questions about the individual respondent except what their role was in the organization.

The surveys were distributed to the buyers through a web link provided by their management team and remained open for seven weeks. The research team had no direct contact with any survey participants. We provided the consent documentation at the start of the survey and communicated that participation was voluntary. We set up the surveys in Qualtrics to automatically create a random and unique code for each buyer survey.

Upon completion, the buyers were asked to provide the unique code to the supplier (for which they completed the supplier transparency portion of the survey) along with a link to the supplier survey and short message requesting the supplier's participation—all of which was provided at the conclusion of the buyer's survey (as seen in Figure 4). The random code authenticated the corresponding supplier's survey. In other words, a supplier could not begin the survey without a code from the buyer, allowing us to match the dyadic responses while still maintaining anonymity.

**Figure 4**

*End of Buyer Survey Communication for Supplier Referral*


Thank you for taking the survey. Your response has been recorded.
**There is just one more important step!**

Please email the supplier survey link and unique supplier code previously provided to your contact at the supplier firm.
**Here it is again for your convenience:**
**Unique supplier code: 99632**
Supplier Survey Link

Here is a note you are welcome to use (in part or in whole) in that email requesting their participation:

Please consider participating in a survey about buyer-supplier relationships.The Schaeffler Group is the focal firm in this study as the customer, so your perspective from the supplier's side of the relationship will help to reach the goal of the research.

Honey Zimmerman, a doctoral student at the University of Missouri-St. Louis, is conducting research to understand the effects of technology and information transparency on a firm's agility within the supply chain. The goal is to provide insight into the value of technology and information exchange within a buyer-supplier relationship.

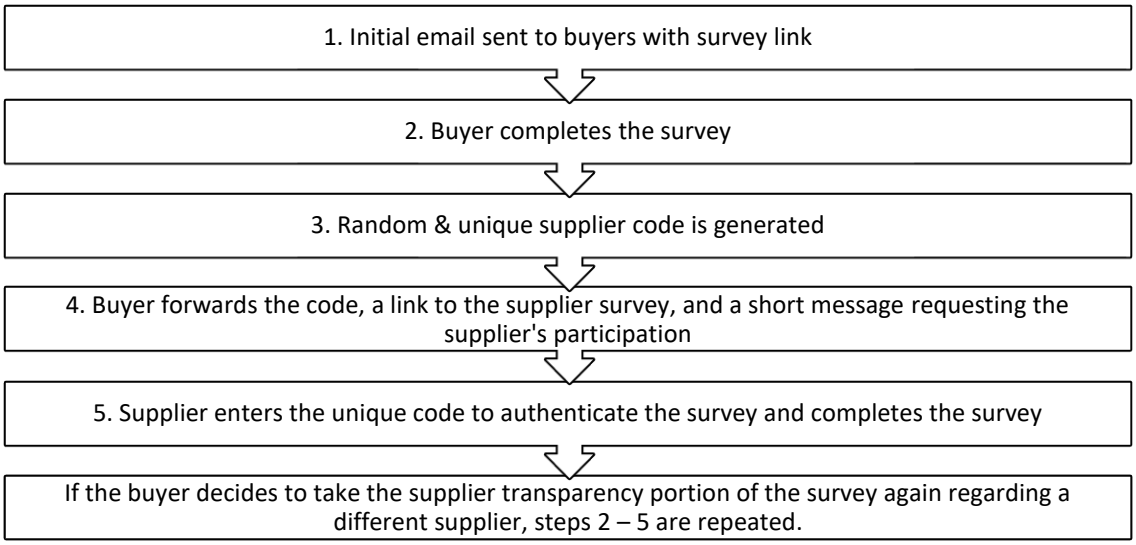
We feel this research on agility is particularly important right now given the supply chain challenges brought on by the global pandemic. If you are willing to complete a short questionnaire, which should only take about 15 minutes and can be done from a mobile device, simply click on the link below and use the unique supplier code to begin.

Buyers could complete the survey more than once, but only for the eight questions specific to supplier transparency. At the beginning of the survey, the respondent was asked if it was their first time completing the survey; if they selected "no," then it restricted the questions to only the ones regarding supplier transparency. Therefore, if a

buyer chose to complete the survey more than once, they would receive a new code each time to forward to the supplier. This allowed us to increase the number of dyadic responses since an individual buyer is usually responsible for the relationships with multiple suppliers while still restricting "ballot stuffing." Figure 5 illustrates the process carried out to distribute the surveys.

**Figure 5**

*Process for Survey Distribution*




### *Phase 2 Validity and Reliability*

Phase 2 utilized a quantitative research approach. Quantitative research methods enable greater control and greater external validity (generalizability) compared to qualitative research (Golicic et al., 2005). As previously mentioned, we implemented mixed methodology nested in a single-case design, which strengthened the robustness of

our study. Gathering multiple sources of evidence allowed us to triangulate the data, providing construct validity with the case study method (Ellram, 1996; Yin, 2018).

We paid considerable attention to the design of the survey instrument, as described in detail in the previous section. We took a few additional steps to strengthen validity. While constructing the survey instrument, we took precautions to minimize the introduction of common method variance (CMV) into the data. Thus, only general information was provided about the study's objectives; no indications were shared about the actual relationships under investigation. We also broke apart scale items across pages of the survey to mitigate the possible impact of CMV (Podsakoff et al., 2003). We assured respondent anonymity and confidentiality to reduce the probability of social desirability influencing responses (Frankel and Frankel, 1977).

The questionnaires containing the constructs described previously were based on existing measurement scales from published research. We did not conduct a factor analysis since the scales were previously validated, and our sample size was small. Meyers et al. (2017) does not recommend conducting principal component analysis, nor factor analysis, for sample sizes less than 200 based on the recommendation of many scholars (i.e., Bryant & Yarnold, 1995; Comrey & Lee, 1992; Gorsuch, 1983). However, to establish face and content validity, we piloted the surveys with nine procurement professionals, six sales professionals, and four academics. Only minor changes were made to the flow logic of the survey instrument upon completion of the pilot test.

We assessed the reliability of the subscales of I4.0 technology implementation, supplier transparency, and FSCA during data analysis, discussed further in Chapter 4, by examining Cronbach’s alpha. An acceptable reliability score is 0.7 or higher (Meyers et

al., 2017). The reliability coefficients were all excellent at .954, .921, and .937, respectively.

### *Summary*

This chapter explained the design of our single-case study and why the mixed methodological approach was most appropriate to answer our research question. We described the study participants of the focus groups and individual interviews utilized for Phase 1. We then discussed the process for data collection and actions taken to enhance the validity and reliability of Phase 1. Then, we explained how Phase 1 led to the hypothesis development for Phase 2. We then described the survey participants, data collection procedures, and concluded with the steps taken to strengthen the validity and reliability of the study's quantitative phase, or Phase 2. The complete data analysis and results will be covered in the next chapter.

# Chapter 4: Data Analysis and Results

This chapter discusses the results of the current study. We first describe how we analyzed the data from Phase 1 and the initial findings that resulted. Then the quantitative analysis and results from the subsequent phase are described in detail.

## *Phase 1 Data Analysis & Qualitative Findings*

We began this investigation as an exploratory study with no hypotheses. We set out to answer the initial research question: Does I4.0 technology influence buyer-supplier relationships and firm supply chain agility? The initial findings of Phase 1 suggested the perception of answering this question was a yes, that the I4.0 technology does affect BSR and FSCA, but how was still unclear.

After completing the focus groups and individual interviews, we wrote analytic memos of our initial thoughts and impressions from the sessions. Then, upon the return of each transcript, we repeated this process after reading through them. This technique allowed us to think through the participants' responses and conceptualize potential codes and categories that might arise during their coding (Saldana, 2016).

Next, we used NVivo software to analyze the qualitative data transcripts through a variety of coding techniques and analytic strategies. We began with open coding using descriptive and In Vivo codes (Saldana, 2016). We analyzed the data through constant comparisons (Corbin & Strauss, 2015) within and across all interviews (group and individual). Upon completion of the initial coding, we then applied sub-coding, assigning "parent" and "children" relationships to the codes, from which we were then able to identify categories and subcategories. (Corbin & Strauss, 2015).

We initially analyzed the respective transcripts from the buyer and supplier sides separately in order to better see the different perspectives. A few common themes emerged in the focus groups that had not come up with the suppliers. For example, the focus groups discussed barriers their suppliers seemed to face regarding technology adoption and the frustrations they had heard from suppliers about technology requests. Although this was important information, it was not as relevant to addressing the research question as other themes that emerged from both sample groups.

The use of data was a common theme between all parties (both buyer and supplier sides). Of the twelve I4.0 technologies identified in prior research by Stentoft et al. (2019) (listed in Appendix A), the focus group and supplier participants all emphasized "big data" and big data analytics as the primary source of change and value in their interactions within the supply chain. One individual from the buying organization commented, "the data amount is every, I would say, month, year, day; it's increasing." Another shared that using special software that "evaluates algorithms of thousands and thousands of components in order to bring into one single picture" brings a lot of efficiency and value to his job. One supplier representative mentioned that in today's technology-based business environment, "the biggest advantage is that there's more information available to more people."

Although big data and analytics were the primary themes regarding I4.0 for both sides, the participants alluded to other I4.0 technologies, including horizontal and vertical system integration, cyber-security, the cloud, additive manufacturing, mobile technologies, radio-frequency identification (RFID), and real-time location systems (RTLS) technologies. Some comments concerned the lack of utilization of such

technology, such as additive manufacturing (3D printing) and RFID, which the participants viewed as an opportunity for growth.

Another central theme that emerged from Phase 1 was the value of data transparency. When asked about the influence of I4.0 technology on being able to adjust to changes in the marketplace, one supplier representative reflected on the disruption in 2020 due to the Covid-19 global pandemic, stating,

> I think technology played a huge role in keeping us going, right? Because from a communication point of view, we were still able to communicate…I have access to other people's information that I wouldn't have had otherwise…where before I'd actually have to physically go to those people and have them give me the information.

This supplier continued to discuss the value of data transparency both internally within an organization and across the supply chain, saying, "a particular topic isn't just targeted to one person, it can be available to whoever you want it to be available to. So you're less dependent on getting information from other people." He gave several examples of inter-organizational supply chain transparency, such as customer complaints, supplier evaluations, and demand forecasting.

On the buyer-side, the concept of information transparency emerged and was discussed in regards to its significance as well. One person stated, "Transparency is a big topic…to have more transparency, which is, I almost want to say, a surviving factor at the moment to keep our production plants running." Another said, "the supplier has more transparency to our data to see what we have in current stock, and also what our demand is." One person added,

> The transparency is…as close to live data without having a constant feed. At least they can see the demand on their side of it as we update schedules…the supplier can see all the changes for the rest of the year in five or ten minutes, as opposed to waiting for some batch process to happen.

Regarding agility, the participants touched on each of the five dimensions of firm supply chain agility (FSCA)—accessibility, swiftness, flexibility, alertness, and decisiveness (Gligor et al., 2013)—throughout the conversations without any prompting or prior discussion of them. Data accessibility was the most discussed topic. One person summed it up well when they emphasized the value of I4.0 is "definitely having that data available and having access to that data 24 hours, 365 days a year." They discussed the importance of swiftness, or speed, as well. One person explained, "having the data that I'm able to access with the different software and simulations that I use, it's making everything faster." Addressing flexibility, one individual said, "we have those tools at our disposal… and the right kind of people to interact and behave with our suppliers…to make (us) more flexible, to make us more reactive." One manager discussed alertness in the context of risk management. He explained that I4.0 technology enables

> getting ahead of the curve on different types of risk, including cyber risk monitoring and the normal commercial things like financial stability and bankruptcies. But we also monitor negative internet chatter and legal filings across the world to make sure nobody's named in a dumping suit or an anti-Fair Trade Act suit or something like that. So, we watch all those

Finally, referring to decisiveness, someone said, “having easy access to the things we track…or direct my attention or energy where I need to make improvements…helps when you’re trying to make a decision.” One of the suppliers discussed that having access to more data allowed them to make decisions more quickly by not involving other people (inside or outside the organization) or asking for information. They said, “Now, I can just go onto our system and find out what scrap rates are, what ASNs are for a particular type of product, where before I was depending and waiting for other people to come back with that information.”

On the other hand, when directly asked about agility, the participants’ tone changed somewhat. The perception expressed by multiple participants from both sample groups was that the lack of integration across systems may stifle agility. For example, the buying organization used several third-party applications that were not integrated into their ERP system, which, according to the focus group participants, hindered their ability to quickly find the information they were looking for. One participant said, “One program does things really the others don’t, so we fill the gaps with other programs, and a lot of times these programs and systems are not talking with each other and facilitating each other effectively.” Another individual from the other focus group mentioned,

> There are so many things that you have to do to get the answer of what you’re searching for or what you’re trying to implement that sometimes it does become a hindrance because it’s not always just a click of a button with technology. Sometimes the applications may cause you to have to do three or four steps before you even get the answer.

The focus group participants also expressed that FSCA was likely limited by a lack of transparency across organizations, particularly from customer to supplier. Discussions arose about the "lack of technology" OEMs were employing to interface with the tier-one suppliers. One individual said, "there is very little beyond the standard old-fashioned EDI communication going on." They continued to explain that the customer publishes spreadsheets to their portal that

> You have to manually download and then decode with codes that they don't tell you, so you're left to do your own sleuthing to get this information into a usable format. We're in a real world of hurt right now… because they didn't prepare their supply base for that…So, as a result, now we are all behind, and we're straining the entire supply chain because there was a significant lack of employing any sort of predictive tools and efficient ways of passing that on to your supply base. So, it really exposed our lack of agility, if nothing else.

The focus group participants commented how they felt the need to constantly react to real-time data changes, which hindered their ability to be agile. For example, one participant said,

> an observation that I see is that sometimes because we have such good communications now, that we think we can be agile. But we're so agile, we stifle ourselves trying to be agile. Right? We have great information. Everything's up to date. We can change to meet somebody else's needs, but you spend more time trying to figure out how to make the change than maybe you do making parts at times. And sometimes the agility could

> actually be a hindrance because of this very short lifespan of validity of the data now…where before…we had more, it seemed like, time between iterations of somebody's demand picture, and now it seems that it's just like live, right?

In other words, is more time spent constantly changing orders based on real-time information? Are organizations constantly reacting to the data as it is received? If so, does this stifles an organization's ability to be strategically agile overall? They also mentioned several basic technologies they were not using that they felt would be very beneficial to their ability to be more proactive and strategic (such as RFID labels to increase visibility).

From Phase 1, we also found that different facilities within the buying firm may have been adopting new technology at varying levels based on regions of the world. The focus group participants referenced systems (e.g., apps, software) that the European facilities had adopted that were not yet utilized in their U.S. locations. An excerpt from one analytical memo expressed further questions this raised with the research team, "Is this true? Is there a difference in the rate of adoption? And if so, why? Do U.S. facilities face greater barriers, or is it more about the resource investment in the corporate region? Is this also true for suppliers in different regions of the world? For example, are small- and medium-size U.S. suppliers further behind with technology adoption than European counterparts?" This discovery, and resulting questions, caused us to expand our participants in both sample groups for Phase 2 so as to include participants beyond North America.

We also found that even though the suppliers we interviewed were considered key suppliers, the level of supplier integration varied significantly across the supply base. This was somewhat expected though, since the level of I4.0 technology implementation varied among the suppliers selected for interviews. For example, one supplier we interviewed did not utilize EDI with the buyer organization; everything was manually entered into the supplier's system from what they viewed on the buyer's supplier portal. The focus group participants from the buying organization discussed several barriers as to why they felt specific suppliers lacked the technology adoption that the buyer firm seeks; however, barriers to technology adoption were beyond the scope of this study.

Lastly, findings suggested that there may be a disconnect between different supplier tiers within the automotive industry. For example, one participant from the buying firm commented that the industry as a whole was attempting to put "jetpacks on dinosaurs," stating that some of the equipment in the manufacturing processes were outdated and did not have the capabilities to connect and integrate across the supply chain. Also, they commented that the OEMs did not seem to integrate very well with the tier-one suppliers. The participants in the focus group expressed the appearance of either a lack of sophistication on the part of the OEMs or maybe intentional effort by the OEMs NOT to be transparent. This again was beyond the scope of the current study but is notable for future research.

In Phase 1, we explored the nature of the buyer-supplier relationships in this case, investigated the implementation of I4.0 technologies within the representative sample, and considered the participants' perceptions regarding I4.0 technology's influence on supply chain agility. The primary goal of this first phase with the qualitative approach

was to inform our hypotheses and what the survey instrument would be for the next stage. Phase 1 allowed us to narrow down the scope of our study leading us into Phase 2.

### *Phase 2 Data Analysis & Findings*

The quantitative phase of the current study consisted of two sample groups as described in Chapter 3—buyers and suppliers—and, therefore, was analyzed in stages. Using covariance and regression analysis, we first analyzed the data from the buying firm and then from the suppliers. Next, we conducted supplemental analysis using t-tests of categorical variables and the matched data in the dyadic relationships. The following sections describe these various examinations in more detail.

#### *Sample 1: Analysis of buyer data*

The initial size for the buyer sample was N=123. After removing 23 incomplete responses, N=100. Before analysis, all codes were cleaned and then screened for statistical assumption violations, missing values, and outliers using IBM SPSS Frequencies, Explore, Missing Value Analysis, and Regression procedures. We created composite scores for the three primary constructs. Fifteen items made up the supplier transparency construct (seven for stakeholder visibility and eight for supplier traceability); FSCA consisted of 14 items. There were four items for I4.0 technology implementation. We recoded responses that reported “no plans of implementation” with a value of “0” into the overall subscales of the four technologies. We computed data screening for the three constructs.

During the data screening, none of the variables revealed a high level of skewness or kurtosis. Specifically, the skewness ranged from -0.216 to 0.328, and the kurtosis

values ranged from -0.704 to -0.551 across the three variables. Univariate outliers were examined using z-scores, boxplots, and normal probability plots. No univariate outliers were discovered, and based on the assessment of normality, we concluded that the variables had an appropriately normal distribution. We also screened for multivariate outliers by examining Mahalanobis distances, with a cutoff of 16.266 based on 3 df at $p<.001$. The maximum value was 9.14039. No multivariate outliers were detected.

As discussed in Chapter 3, we examined Cronbach's alpha to assess the reliability of the subscales for FSCA, supplier transparency, and I4.0 technology. The reliability coefficients were .937, .921, and .954, respectively, which indicated excellent reliability (Meyers et al., 2017). We did not conduct a factor analysis since the scales were previously validated, and our sample size was small. Meyers et al. (2017) does not recommend conducting principal component analysis or factor analysis for sample sizes less than 200 based on the recommendation of many scholars (i.e., Bryant & Yarnold, 1995; Comrey & Lee, 1992; Gorsuch, 1983).

We conducted bivariate correlation to test our hypotheses using the Pearson r index to determine if there was a relationship between the variables and we used simple linear regressions to measure effect size ($R^2$). The analysis revealed that there was a negative correlation between supplier transparency and I4.0 technology implementation ($r = -.315$, $p < .001$, $R^2 = .099$), as well as between FSCA and I4.0 technology implementation ($r = -.237$, $p = .010$, $R^2 = .056$). Although the correlations were statistically significant in both cases, the residual variance ($1-R^2$) indicated other factors besides the technology accounted for the variation in supplier transparency and FSCA. Therefore, H1 and H2 were not supported. However, we found a positive and statistically

significant correlation between supplier transparency and FSCA (r = .781, p < .001). We then conducted a regression analysis with supply chain agility as the outcome variable to reveal an effect size of $R^2$=.609, suggesting that supplier transparency accounted for 60.9 percent of the variance in FSCA within the buyer sample. H3 was, therefore, supported.

Next, we conducted multiple regression for further analysis of the three variables together. The prediction model was statistically significant, F(2,94) = 66.676, p < .001. Supplier transparency and I4.0 technology implementation together explained 59.2 percent of the variance in FSCA; however, after reviewing the coefficients, the technology implementation was not significant (p=.930). The results, which were not surprising given the earlier findings, are shown in Figure 6. We concluded that, when considered together, supplier transparency explained a large portion of the variance, but the implementation of I4.0 technology did not have an effect on FSCA.

**Figure 6**

*IBM SPSS Multiple Regression Results for Buyer Sample*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .769[a] | .592 | .583 | .36773 | .592 | 66.676 | 2 | 92 | <.001 |

a. Predictors: (Constant), ST_COMP, NEWTECHCOMP

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 18.032 | 2 | 9.016 | 66.676 | <.001[b] |
| | Residual | 12.441 | 92 | .135 | | |
| | Total | 30.473 | 94 | | | |

a. Dependent Variable: FSCA_COMP

b. Predictors: (Constant), ST_COMP, NEWTECHCOMP

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | | Correlations | | |
|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. | Zero-order | Partial | Part |
| 1 | (Constant) | .431 | .176 | | 2.448 | .016 | | | |
| | NEWTECHCOMP | .003 | .036 | .006 | .088 | .930 | -.237 | .009 | .006 |
| | ST_COMP | .636 | .058 | .771 | 10.986 | <.001 | .769 | .753 | .732 |

a. Dependent Variable: FSCA_COMP

***Sample 2: Analysis of supplier data***

The initial size for the supplier sample was N=80. Fifteen incomplete responses were removed, leaving a sample size of N=65. All codes were cleaned before analysis. We screened the data for statistical assumption violations and outliers using IBM SPSS Frequencies, Explore, and Regression procedures. We created composite scores for the three main constructs and conducted data screening as we did with the other sample.

During the data screening, the skewness and kurtosis values for composites of FSCA (skewness -.021, kurtosis -.948) and I4.0 technology implementation (skewness -.158, kurtosis -.545) were acceptable. However, skewness and kurtosis were beyond the +/- 1.00 level for supplier transparency, 1.103 and 3.452, respectively (Meyers et al., 2017). Univariate outliers were examined using z-scores, boxplots, and normal probability plots. Likewise, no univariate outliers were discovered for FSCA and I4.0 technology. Based on the assessment of normality, we concluded that these variables had an appropriately normal distribution. However, for supplier transparency, two outliers were discovered using boxplots and Q-Q plots. After further examination, we removed one outlier case based on the abnormal response (all the survey questions marked as extreme). After removal, we re-checked the data to confirm there were no new outliers which there were not and that normality held after removal which it did. Also, skewness

and kurtosis then became acceptable (.075 and -.133, respectively). We also screened for multivariate outliers, before and after removing the outlier, by examining Mahalanobis distances, with a cutoff of 16.266 based on 3 df at $p<.001$. The maximum value was 22.8268 before removing the outlier and 9.85366 after removal. When the one outlier was removed from the data, the scores appeared to be multivariate and univariate normal for supplier transparency. Accordingly, this case was removed for any subsequent analyses, and the resulting sample size was N=64.

We used the same process for this dataset to test our hypotheses as we did the buyer sample. Bivariate correlations using the Pearson r index were conducted to determine a relationship between the variables, followed by simple linear regression to measure effect size ($R^2$). Similar results were revealed in this sample as the previous sample. H1 and H2 were unsupported. Supplier transparency and I4.0 technology implementation exhibited a negative association ($r = -.318$, $p = .006$, $R^2 = .101$). Similarly, there was a negative association between FSCA and I4.0 technology implementation ($r = -.176$, $p = .084$, $R^2 = .031$); however, it was not statistically significant at the .05 alpha level. Supplier transparency and FSCA were positively correlated ($r = .432$, $p < .001$, $R^2 = .186$), supporting H3.

Next, we conducted multiple regression to further analyze the variables in this sample group as well. With FSCA as the outcome variable, the regression analysis revealed that the prediction model was statistically significant, $F(2,62) = 6.755$, $p = .002$. Still, only 18.4 percent of the variation in FSCA was explained by supplier transparency and I4.0 technology implementation. A review of the coefficients revealed the technology implementation was not significant ($p = .719$). The results of the multiple regression for

the supplier sample are shown in Figure 7. We concluded that, when considered together, I4.0 technology implementation had no effect on the variation in firm supply chain agility.

**Figure 7**

*IBM SPSS Multiple Regression Results for Supplier Sample*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .429[a] | .184 | .157 | .41283 | .184 | 6.755 | 2 | 60 | .002 |

a. Predictors: (Constant), NEWSuppTran, COMPTech

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2.303 | 2 | 1.151 | 6.755 | .002[b] |
| | Residual | 10.226 | 60 | .170 | | |
| | Total | 12.528 | 62 | | | |

a. Dependent Variable: COMP_FSCA

b. Predictors: (Constant), NEWSuppTran, COMPTech

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Correlations | | |
|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Zero-order | Partial | Part |
| 1 | (Constant) | 1.211 | .238 | | 5.096 | <.001 | | | |
| | COMPTech | -.016 | .043 | -.044 | -.362 | .719 | -.176 | -.047 | -.042 |
| | NEWSuppTran | .301 | .090 | .412 | 3.353 | .001 | .427 | .397 | .391 |

a. Dependent Variable: COMP_FSCA

***Supplemental Analysis: T-tests***

We conducted multiple independent samples t-tests to compare mean differences between two groups. In total, we conducted 55 different t-tests: 11 with the buyer data and 44 with the supplier data. The null hypothesis for each t-test was that no statistically

significant difference existed in the sample means of the two groups. Then, the alternative hypothesis that emerged was a statistically significant difference in means between the two groups being tested.

One series of t-tests consisted of grouping country of operation into three regions—Americas, Europe, and Other—based on the regions defined by the focal firm for both sets of data (buyer data and supplier data). As an example of the groupings, we assigned those indicating a European country of operation a code of 1 and all others a code of 0. We did the same for another test wherein the Americas = 1 and Non-Americas = 0. We did this for both sets of data separately (buyer and supplier).

There were no statistically significant differences in the means of the groups concerning I4.0 technology adoption and supplier transparency for the buyer sample. However, when comparing FSCA in the Americas and non-Americas, there was a statistically significant difference in the scores for the Americas (M=2.2610, SD=.34665) and Non-Americas (M=1.7940, SD=.60716). Lower means corresponded with higher levels of agility. Levene's test for equality of differences is statistically significant; therefore, we did not assume equal variances and $t(94.24) = -4.875$, $p<.001$. So, for this particular test, we rejected the null hypotheses that there was no difference in the two independent samples. These results suggested that the country of origin may affect FSCA. Specifically, our results suggested that buyers in the Americas region perceived their organization's supply chain to be less agile than those in other regions of the world.

For the supplier data set, regarding FSCA, there was a statistically significant difference in the means for suppliers with operations in the "other" region (M=1.99, SD=1.3199) compared to suppliers with operations in the Non-Other category (which

included European and America regions combined) (M=2.2829, SD=1.2469). Assuming equal variances, t (62) = 2.836, p = .006 with a medium effect size (Cohen's d = .727). Similar results were obtained for suppliers with Asia/Pacific *ownership* (M=1.6585, SD=.40178) when compared to those with Non-Asia/Pacific ownership (M=1.9013, SD-.46371). Assuming equal variances, t (62) = 2.223, p = .030 with an effect size of Cohen's d = .557. This suggested that suppliers in the Asia Pacific region perceived the supply chain of their own organizations as being more agile than the suppliers in the Americas and European regions.

Concerning supplier transparency in the supplier data, the independent samples t-test regarding firm ownership by region indicated a statistically significant difference in the means for those in the Americas region (M=2.3867, SD=.62447) as opposed to Non-America regions (M=1.9390, SD=.57517), with t (62) =-2.586, p=.012. This suggested that suppliers from the Americas perceived lower transparency overall than those from the non-America regions.

For both data sets, we also grouped responses based on the question, "has your organization adopted as least one of the I4.0 base technologies," with answers of yes (1) and no (0). We conducted two additional independent t-tests for the buyer sample: one comparing FSCA in groups with I4.0 adoption and one without, and the other comparing supplier transparency in groups with I4.0 adoption and one without. There was no significant difference in the means of the two groups; therefore, we accepted the null hypotheses. We obtained the same results with the same tests for the supplier data. The complete list of t-test results can be found in Appendix K.

For the supplier data, several additional independent sample t-tests were conducted. We compared means for the three variables for the following: small to medium-size firms (SME), whether the organization was a subsidiary of a parent organization, and the industries served. The full list of t-test results can be found in Appendix K. There were several statistically significant differences in means in these tests, all with medium effect size, and therefore, were worth reporting. First, small to medium size (SME) suppliers exhibited less perceived transparency (M=2.1910, SD=.599) and lower firm supply chain agility (M=1.883, SD=.4412) than larger organizations (M=1.842, SD=.112 and M=1.657, SD=.420 respectively). SMEs were defined as companies with fewer than 500 employees. With regard to I4.0 technology implementation, the means for subsidiaries (M=2.525, SD=1.1714), as well as those in the industrial (M=2.4722, SD=1.2884) and energy sectors (M=2.75, SD=1.115), exhibited higher levels of 14.0 technology implementation than non-subsidiaries (M=1.84, SD=1.293), non-industrial (M=1.759, SD=1.155), and non-energy (M=1.951, SD=1.272) firms.

Cohen's d is the most common method for determining the effect size of mean differences. The rule of thumb is less than 0.5 is a small effect size, 0.5 to 0.8 is a medium effect size, and greater than 0.8 indicates a large effect size (Cohen, 1988). Our tests showed a medium effect size for all samples in which the null hypotheses were rejected.

Based on the results of the t-tests performed, we ran additional multiple regression analyses adding firm characteristics to the models with FSCA still the dependent variable. For the buyer data, adding region of operation for those in the "other"

(non-Americas and non-European) regions was statistically significant ($p < .001$) in adding to the explanatory power. The adjusted $R^2$ (.624) was higher than with supplier transparency alone (adjusted $R^2 = .587$).

For the supplier data, we added the size of the firm, region, and industry to I4.0 technology implementation and supplier transparency as independent variables. Specifically, we looked at large firms with ownership in the Asia-Pacific region in the industrial and energy sectors, based on the t-tests. In this model ($R^2 = .282$, adjusted $R^2 = .205$, $p = .004$), supplier transparency ($\beta = .291$, $p = .003$) and Asia-Pacific ownership ($\beta = -.231$, $p = .034$) were the only predictors that were statistically significant in explaining the variance in FSCA. The best fitting regression model, based on the adjusted R2, included only supplier transparency and Asia-Pacific ownership as predictors (adjusted $R^2 = .206$, $p<.001$). So, we conclude that Asia-Pacific ownership helps explain the variation in FSCA in the supplier sample.

***Supplemental Analysis: Dyadic Examination***

We collected matched sets of buyer-supplier data to evaluate both parties' perceptions of the supplier firms' transparency in a single supply chain relationship. As previously described, the supplier transparency scale included 15 items to measure two dimensions: stakeholder visibility and supplier traceability. The seven stakeholder visibility questions asked the respondent about their own firm; however, the eight supplier traceability questions asked about their supplier. So we modified those eight questions in the buyers' survey to be about one specific supplier. Then we changed the same eight questions in the suppliers' survey. In the suppliers' survey, they were asked about their own practices regarding transparency with the buying firm. For example, one

question on the buyer survey stated, “This supplier provides Company XYZ with operational plans (e.g., distribution plan, production plan) regarding the products they produce for us.” The same question on the supplier survey states, “Our firm provides Company XYZ with operational plans (e.g., distribution plan, production plan) regarding the products we produce for them.” Therefore, these eight questions in both surveys were about the supplier firm. The complete list of questions is in the corresponding surveys in Appendix I and J.

We wanted to see if there was a difference in perceptions regarding transparency of the supplier, so we analyzed matched pairs using paired samples t-test. There were three supplier firms where more than one representative completed the survey, so for those cases, we averaged their responses resulting in one single score. Therefore, N=53. The null hypothesis is H0: $\mu D = 0$; in other words, the mean difference of perception of supplier transparency between the dyads was zero.

The paired samples t-test revealed that suppliers perceived their transparency with the buyer firm (M=2.1718, SD=.6877) to be greater than that of the perception of the buyer firm (M=2.5232, SD=.71411). A higher mean was equivalent to lower perceived transparency, so this was consistent with prior literature that found a significant difference in perceptions of buyers and suppliers when it came to relationship characteristics (Ambrose, Marshall, & Lynch, 2010). With a critical value of 2.01 at $\alpha$=.05, the results indicated a statistically significant difference of means t (52) = -2.644, p=.011 with a large effect size (Cohen’s d = .96776). Therefore, we concluded that there was a significant difference in perceptions of buyers and suppliers regarding the level of supplier transparency.

### *Summary*

Chapter 4 described the data analysis and research findings in this study. First, the qualitative portion, Phase 1, was discussed. This analysis involved using NVivo software to analyze the qualitative data transcripts through a variety of coding techniques and analytic strategies. From the results of Phase 1, we narrowed the scope of two of the three variables for Phase 2. While keeping FSCA the same as initially planned, we limited our focus to just the four base technologies of I4.0 and the buyer-supplier relationship variable to just one dimension—information-exchange mode—by looking at supplier transparency. For Phase 2, we described the various analyses conducted using SPSS, including covariance and regression analysis, numerous independent samples t-tests, and a paired t-test used to analyze the difference in perceptions between the buyer sample and supplier sample regarding supplier transparency. We will discuss the results and implications of those findings in Chapter 5.

# Chapter 5: Discussion

This chapter is organized into six sections in order to discuss and conclude this study. First, a brief overview of the research is provided, including our summarized findings. Then, contributions of the research are discussed in terms of implications for both research and practice, followed by a discussion of limitations of the study and future research directions.

## *Overview of the Research*

The purpose of this research was to explore if I4.0 technology influences buyer-supplier relationships and supply chain agility, and if so, how. For this single-case study, we used mixed methods for data collection—data was collected and analyzed in two phases through focus groups and individual interviews (qualitative) and surveys (quantitative) of a single buying firm and a sample of its suppliers. We implemented an "embedded" design into the study, which involves units of analysis at more than one level (Yin, 2018). For example, survey respondents answered questions about their own firm regarding I4.0 technology and supply chain agility, so the firm was the unit of analysis. Additionally, we analyzed perceptions of supplier transparency within matched buyer-supply dyads. Therefore, the "embedded" units of analysis were the interorganizational relationships.

The results of Phase 1 indicated that the answer to the first part of the research question was yes, that I4.0 technology influences buyer-supplier relationships and the supply chain agility of an organization. The participants portrayed the importance and significant impact of big data, one of the I4.0 technologies, upon their operations and

processes. Several participants (both buyers and suppliers) verbalized a strong connection between the amount, availability, and timing of data with transparency and FSCA, as discussed in Chapter 4. Without prompting, the five dimensions of firm supply chain agility (flexibility, swiftness, accessibility, alertness, and decisiveness) were all discussed in Phase 1. The participants associated big data, big data analytics, and data transparency with enhancements in each of those dimensions. As for the specific I4.0 technologies discussed in Phase 1, most of the participant-led discussions (and therefore subsequent findings) specifically revolved around big data and big data analytics.

The second part of our research question was: *how* does I4.0 technology influence BSRs and FSCA? Based on the Phase 1 findings, we propose that I4.0 technology influences buyer-supplier relationships by creating a mechanism for exchanging information between supply chain partners, creating greater access to information and the flow of information. The Phase 1 participants referred to this exchange and flow of information as transparency. We, in turn, submit that transparency positively influences the agility of a firm's supply chain.

Based on the Phase 1 results, we narrowed the I4.0 technologies down to four base technologies (the cloud, big data, big data analytics, and Internet of Things). We narrowed the buyer-supplier relationship dimension to information exchange by explicitly looking at supplier transparency for Phase 2. This concept emerged from the interviews, a result we were not anticipating; therefore, we decided to investigate it further.

For Phase 2, we first examined if there were correlations between the three constructs (I4.0 technology implementation, supplier transparency, and FSCA). Our

hypotheses stated that we expected a positive correlation for each bivariate analysis. In both buyer and supplier samples, we found support for a statistically significant, positive relationship between supplier transparency and FSCA. However, we did not get the same results for the association between supplier transparency and I4.0 technology implementation or with the association between I4.0 technology implementation and FSCA. Instead, a statistically significant negative correlation was discovered, as discussed in Chapter 4. The results are summarized in Table 4.

**Table 4**

*Summary of Results*

| Hypotheses | Results | Explanation of results |
|---|---|---|
| H1: Supplier transparency is positively related to I4.0 technology implementation. | Buyer sample: *unsupported*<br><br>Supplier sample: *unsupported* | We found a statistically significant, negative association between I4.0 technology implementation and supplier transparency. |
| H2: I4.0 technology implementation is positively related to firm supply chain agility. | Buyer sample: *unsupported*<br><br>Supplier sample: *unsupported* | We found a statistically significant, negative association between I4.0 technology implementation and firm supply chain agility. |
| H3: Supplier transparency is positively related to firm supply chain agility. | Buyer sample: *supported*<br><br>Supplier sample: *supported* | We found support for a statistically significant, positive relationship between supplier transparency and firm supply chain agility in the two samples in this study. |

We went a step further to determine the effect size for each relationship with regression analysis. The residual variance ($1-R^2$) for H1 and H2 indicated other factors

besides the technology accounted for most of the variation in supplier transparency and FSCA. This presents an opportunity for additional investigation in future research.

When we conducted a regression analysis with supply chain agility as the outcome variable and supplier transparency as the predictor variable, it revealed an effect size of $R^2$=.609, suggesting that supplier transparency accounted for 60.9 percent of the variance in FSCA within the buyer sample. Although it does not answer our initial research question regarding the I4.0 influence, this is an important finding with significant implications for both research and practice, which we will discuss further in subsequent sections.

Additional quantitative analysis was conducted in Phase 2, revealing findings that apply to our research question regarding I4.0 technology. Numerous independent samples t-tests were performed to examine mean differences based on various characteristics of the sample. Regarding I4.0 technology implementation within the supplier firms that participated in our study, we found that subsidiaries of larger parent companies perceived higher levels of I4.0 technology implementation than non-subsidiaries. Additionally, supplier firms serving industrial and energy sectors also perceived higher levels of I4.0 technology implementation compared to groups who were not part of those sectors. Although this does not answer the research question about the influence of I4.0 technology on buyer-supplier relationships and FSCA, it gives us insight into areas for future research opportunities such as firm characteristics that may imply they are further along in adopting such technologies.

Lastly, we compared the perceptions of supplier transparency in the matched dyads of buyers and suppliers with a paired samples t-test. The results revealed a

significant difference in perceptions of buyers and suppliers regarding the transparency of the supplier.

### *Implications for Research*

The most significant contribution of this study is the relationship detected between transparency and firm supply chain agility. We discovered this phenomenon with our qualitative analysis and then empirically tested the relationship with the quantitative data. In both sample groups, we found that supplier transparency explained a sizeable portion of the variance in FSCA. Therefore, we conclude that the link between transparency and agility is an important finding that needs further examination. Supply chain agility and supply chain transparency are both topics which continue to grow within supply chain management and logistics research. Although some existing literature discusses the importance of information sharing for enhancing agility, we did not find any research that directly studied this phenomenon.

Additionally, this study adds to an existing knowledge base. Our findings support previous research concluding that big data is critical for decision-making in today's business environment. As discussed in Chapter 2, the foundation of I4.0 technologies revolves around data. The findings in Phase 1 of this study emphasize the influence big data has on a firm's supply chain agility. Participants from both samples discussed all of the dimensions of FSCA (Gligor et al., 2013) in the context of data without any prior discussion of them, demonstrating an important association between data and agility.

Although we did not find a difference in the means of small to medium-size firms (SMEs) compared to larger ones regarding I4.0 technology implementation as found in prior research, we did find a statistically significant difference in the means of

subsidiaries of larger parent companies compared to non-subsidiaries. We also found that SMEs exhibit lower levels of perceived transparency and lower FSCA. This is another contribution of our study, suggesting further research be conducted to explore these differences.

Finally, the results of this study show a difference in perceptions regarding the level of information transparency between buyers and suppliers, another scholarly contribution. Dyadic research is not common due to its complexity; however, this type of research can often provide rich insight. We found differences in perceptions that could directly impact the strategic performance of a firm by affecting the agility of its supply chain. This is useful information for researchers and identifies an aspect of inter-organizational relationships that warrant further investigation.

### *Implications for Practice*

The current study has practical implications as well. This study highlights the importance of information exchange within a supplier network. The positive relationship found between supplier transparency and FSCA implies that greater transparency may have a sizable effect on the strategic agility of a firm's supply chain. Since agility is the central trait of the best supply chains (Lee, H., 2004), the link between supplier transparency and FSCA is significant for companies to recognize. Firms should intentionally strive for increased supplier transparency through relationship building and collaboration (Heric & Singh, 2010; Narayanan et al., 2015; Vanpoucke et al., 2014; Wagner & Bode, 2014), which in turn could lead to greater competitive advantage (Monczka et al., 1998).

The inference in our study—that suppliers perceive they are more transparent than the buyer feels they are—calls for increased communication between the supply chain partners about what information is collected and shared within their relationship. As indicated in the participants' comments in Phase 1 (as well as in extant literature), trust likely influences willingness to be transparent and share information (Cheng et al., 2008; Dyer & Chu, 2003); however, we did not examine the effect of trust in Phase 2 of our study. It is important to communicate expectations (in both directions) within a relationship and have regular feedback whether those expectations are being met or not.

We can also infer from the findings of this study that opportunities exist for supplier development initiatives with SMEs. Extant literature shows SMEs face greater barriers to I4.0 technology implementation and possess lower I4.0 readiness than larger companies (Stentoft et al., 2019). Our study suggests SMEs may also exhibit lower levels of transparency and lower FSCA than larger organizations. Therefore, it is essential that organizations sourcing from small suppliers are aware of the power transparency holds when making strategic supply management decisions. Whether transparency is viewed as an opportunity or a threat may depend on resource availability and perspective; nevertheless, its influence on FSCA is now more evident.

Lastly, the buying firm had a range of responses about the technology implementation. For example, 52 responses indicated some level of implementation (ranging from low to advanced) of cloud services, and 42 suggested that the company had not yet implemented cloud services (with eight indicating no plans to implement). Similarly, for big data, 49 indicated some level of implementation, and 45 indicated no implementation. The split in the responses were similar for big data analytics (51 and 43

respectively) and IoT (45 and 49 respectively). This is a wide range of responses regarding the implementation of 14.0 technology at the focal firm. Therefore, we wondered if the respondents' split perceptions are reflective of reality? In other words, are some locations or regions really that more advanced than others? Or, is it that the respondents—who were purchasing professionals, not IT experts—did not realize that the firm used cloud services? If it is the latter, this may suggest that the organization lacks communication or training about the various I4.0 technologies that the firm has adopted. These questions also suggest there may be an important distinction to be made between I4.0 implementation at the firm level and the use of the technology by their employees.

### *Limitations*

First, this study was based on a single case—one focal firm and its suppliers—automatically limiting its scope. Although we justified the use of a single-case because of the exploratory nature of the study and the complex embedded design, using a multiple-case design is preferable. When investigating a single firm, or even a small number of firms, making strong inferences is difficult. Investigating the phenomenon across multiple firms within multiple industries would enhance the study's generalizability (external validity) with less scrutiny.

A second limitation of the study is that we only looked at one link in the supply chain, which was between Tier-1 and Tier-2 suppliers from an OEM perspective. The insights could have been richer had we included the OEM's perspectives in the study as well. This may have enabled us to gain a greater perspective of the influence of I4.0 technology implementation on supply chain agility and upon different relationships within a supply chain network. Additionally, in Phase 2 of our study, we focused on

supplier transparency, insinuating one-directional transparency. This was a limitation, and more research should be done on bi-directional transparency on a firm's supply chain agility.

A third limitation of the study is the small sample size of the dyadic analysis. Although dyadic data collection and subsequent analysis can add a great deal of information to fill an existing knowledge gap, they are challenging and time-consuming. Additionally, we only chose to analyze the data collected from the matched pairs of buyers and suppliers for the eight supplier transparency questions in the questionnaires.

A final limitation of the study worth noting is that the research team did not have direct contact with any participants; therefore, control over correspondence and distribution was somewhat limited. For example, we could not send direct reminders to potential participants and instead had to rely on the management team to relay the information. Working through a single company for data collection presents confidentiality and policy concerns. Therefore, the research team needed to work with the workers' council, legal department, and leadership team to obtain the required permissions to collect both qualitative and quantitative data. Although these additional precautions were not difficult to implement, they did cause some delays.

### *Future Direction*

The scholarly research on topics related to I4.0 technology, supply chain agility, and supplier (and supply chain) transparency is limited, so several possible future research directions are worth mentioning. The interesting findings in this study also indicate there is a need for continued research in this domain.

First, we suggest a strong association exists between supplier transparency and firm supply chain agility. This warrants further research as it could have significant managerial implications on a global level for managing complex supply chains. Future research in this area could benefit from a longitudinal study in order to observe how transparency and agility change over time and to determine a causal link.

Although we did not find a positive association between I4.0 technology implementation and the other variables in our quantitative analysis, it would be worth replicating this study with a larger sample size across more firms and industries. As companies presumably invest in more I4.0 technologies in the future, particularly those technologies that target information sharing and transparency, further research will be essential in this area.

Future research should also incorporate the aspect of analyzing trust. To purely explore the relationships between variables as a starting point, we maintained a reasonably simplistic analysis. We left out some seemingly important factors that likely should have been included, such as trust. Trust appeared in both the literature and the qualitative data; however, we opted to leave it out of Phase 2 to first explore if relationships existed between variables. Although this is a potential limitation of the current study, it leaves opportunities for future researchers.

Our results suggest several observable differences in perceptions between different regions of the world, including lower agility and less transparency in the Americas and higher agility in the Asia Pacific region. This could be due to tendencies for bias in self-reporting within different cultures, but further research—with a larger sample size—should compare agility and transparency across cultures.

Finally, more dyadic research about supply chain partners is needed (Morgan et al., 2018; Whipple et al., 2015). Exploring differences in perceptions within the supply chain network to understand relationships and how to enhance collaboration and efficiency could, in turn, lead to more insights for improving performance and agility. Expanding dyadic research, specifically about supply chain transparency and supply chain agility, is recommended.

### *Conclusion*

Continual assessment is essential to better understand how supply chain relationships and performance are affected by the proliferation of advancing technologies, such as those considered in this study. The motivation for this research began with a desire to learn more about the return on investment of I4.0 technologies. We explored intangible benefits by investigating if and how I4.0 technology influences buyer-supplier relationships and firm supply chain agility. Through phases, we narrowed our research, ultimately focusing on supplier transparency within the BSR. The findings of this study have both scholarly and practical implications and provide several suggestions for future research.

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## Appendix A: Industry 4.0 technology definitions

| | |
|---|---|
| **1. Internet of Things (IoT)** | |
| Internet of Things defined | "a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction" (Gillis, 2021).<br>Source: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT |
| **2. Big Data Analytics** | |
| Big data analytics defined | "The use of advanced analytic techniques against very large, diverse data sets that include structured, semi-structured and unstructured data, from different sources, and in different sizes from terabytes to zettabytes" (IBM, n.d.a).<br>Source: https://www.ibm.com/analytics/hadoop/big-data-analytics |
| Additional definitions for big data analytics | • "Involves the data storage, management, analysis, and visualization of very large and complex datasets" (Russom, 2011).<br>• "Consists of an expansive collection of data (large volumes) that are updated quickly and frequently (high velocity) and that exhibit a huge range of different formats and content (wide variety)" (Davis, 2014).<br>• Includes many types of data including, but not limited to: "(1) traditional enterprise data, (2) machine-generated/sensor data (e.g., weblogs, smart meters, manufacturing sensors, equipment logs) and (3) social data" (Opresnik & Taisch, 2015). |
| Examples of tools used for analyzing big data. | R programming language, Hadoop, Salesforce Einstein Analytics, Tableau, SAP Analytics Cloud, SAP BusinessObjects BI, SAP BW/4HANA, Cisco Nexus, Microsoft Azure, Databricks |
| **3. Artificial Intelligence (AI)** | |
| Artificial intelligence defined | "The capability of a machine to imitate intelligent human behavior" (Merriam-Webster, n.d.). |

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|---|---|
| Additional definitions for AI | • an accumulation of "technological components that collect, process, and act on data in ways that simulate human intelligence. Like humans, AI solutions can apply rules, learn over time through the acquisition of new data and information (i.e., via ML), and adapt to changes in their environment" (Russell & Norvig, 2016).<br>• "a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Haenlein & Kaplan, 2019). |
| AI Examples | SAP Chatbots, SAP S/4HANA, Azure Machine Learning, Slack's work graph, Amplero, Drift |
| **4. Autonomous robots** | |
| Autonomous robots defined | "Intelligent machines capable of performing tasks in the world by themselves, without explicit human control" (Bekey, 2005). |
| Examples of types of autonomous robots | Drones, robotic arms, AGV units (automated guided vehicles), collaborative robots |
| **5. Mobile Technologies** | |
| Mobile technologies defined | "Technology that goes where the user goes. It consists of portable two-way communications devices, computing devices and the networking technology that connects them" (IBM, n.d.b).<br>Source: https://www.ibm.com/topics/mobile-technology |
| Examples of mobile technology | GPS, apps on mobile devices (smartphones, tablets, laptops, etc.) |
| **6. Simulations** | |
| Simulation defined | "The use of a mathematical or computer representation of a physical system for the purpose of studying constraint effects" (Gartner, n.d.d).<br>Source: https://www.gartner.com/en/information-technology/glossary/simulation |
| Additional definitions for simulation | • "The use of a model to investigate the behaviour of a business system." Which can range "from spreadsheets models, system dynamic simulations, and discrete-event simulations" (Greasley, 2017). |

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|---|---|
| | • "a replication of a real-world process or event in an environment that is isolated or disconnected from its real-world counterpart" (Mosimtec, n.d.). |
| Examples/types of simulations | Experiential games, Monte Carlo/Risk Analysis simulation, Simio, AnyLogic, Arena |
| **7. Additive Manufacturing** | |
| Additive manufacturing defined | "The industrial production name for 3D printing, a computer-controlled process that creates three-dimensional objects by depositing materials, usually in layers" (TWI, n.d.).<br>Source: https://www.twi-global.com/technical-knowledge/faqs/what-is-additive-manufacturing |
| **8. The Cloud** | |
| The Cloud defined | "servers that are accessed over the Internet, and the software and databases that run on those servers. Cloud servers are located in data centers all over the world. By using cloud computing, users and companies don't have to manage physical servers themselves or run software applications on their own machines"(Cloudflare, n.d.).<br>Source: https://www.cloudflare.com/learning/cloud/what-is-the-cloud/ |
| Examples of cloud services | Hadoop, Dryad, Amazon S3, Nimbus, Eucalyptus, Cloud Burst |
| **9. Augmented Reality (AR)** | |
| Augmented reality defined | "The real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. It is this "real world" element that differentiates AR from virtual reality. AR integrates and adds value to the user's interaction with the real world, versus a simulation" (Gartner, n.d.a).<br>Source: https://www.gartner.com/en/information-technology/glossary/augmented-reality-ar |
| Examples of AR | AR glasses (i.e., training, warehouse picking, assembly line workflow), consumer shopping apps (i.e., IKEA furniture in your home, Home Depot's Project Color) |
| **10. Real time location systems (RTLS) and Radio Frequency Identification (RFID)** | |

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|---|---|
| Real time location systems (RTLS) defined | "sometimes called Indoor Positioning Systems (IPS), let you track and manage people or assets moving through your facility" (Palter, 2021).<br>Source: https://www.realtimenetworks.com/blog/ultimate-2019-real-time-location-system-rtls-tech-guide |
| Radio Frequency Identification (RFID) defined | "an automated data collection technology that uses radio frequency waves to transfer data between a reader and a tag to identify, track and locate the tagged item" (Gartner, n.d.c).<br>Source: https://www.gartner.com/en/information-technology/glossary/radio-frequency-identification-rfid |
| **11. Horizontal and vertical system integration** | |
| Horizontal system integration defined | "connected networks of cyber-physical and enterprise systems that introduce unprecedented levels of automation, flexibility, and operational efficiency into production processes. This horizontal integration takes place at several levels: on the production floor, across multiple production facilities, and across the entire supply chain" (Manufacturing Business Technology, 2019).<br>Source: https://www.mbtmag.com/business-intelligence/article/13251083/horizontal-and-vertical-integration-in-industry-40 |
| Vertical system integration defined | "Vertical integration in Industry 4.0 aims to tie together all logical layers within the organization from the field layer (i.e., the production floor) up through R&D, quality assurance, product management, IT, sales and marketing, and so on" (Manufacturing Business Technology, 2019).<br>Source: https://www.mbtmag.com/business-intelligence/article/13251083/horizontal-and-vertical-integration-in-industry-40 |
| | |
| **12. Cyber Security** | |
| Cyber security defined | "The combination of people, policies, processes and technologies employed by an enterprise to protect its cyber assets" (Gartner, n.d.b). |

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| | Source: https://www.gartner.com/en/information-technology/glossary/cybersecurity |

## Appendix B: Phase 1 email introduction to focus group participants

Hello! My name is Honey Zimmerman, a doctoral candidate at the University of Missouri-St. Louis. As (insert name here) mentioned in the introductory email, I am requesting your participation in a research project about the influence of Industry 4.0 (I4.0) technology in business.

(Insert company name here) has positioned themselves as an innovative global automotive and industrial supplier with a focus on technology and has granted me access to personnel to help me investigate if I4.0 technology influences buyer-supplier relationships and supply chain agility.

In order to learn more, I am requesting your participation in a focus group interview. The focus group will include up to twelve people from your organization with direct supplier interactions. If you agree to participate, this group interview will last no more than one hour. Virtual interviews using video conferencing technology will begin in February.

To learn more about this topic, I will be asking questions such as:

- How do you think the I4.0 technology adds value?
- Which technologies do you find most useful?
- Please describe if and how you feel the technology has impacted supplier relationships.

Attached to this email is a copy of the consent document for your record. If you are willing to participate in this study, please simply respond to me by (insert date here). If you have any questions or concerns about the information provided, please don’t hesitate to contact me via email or call me at (insert phone number here).

## Appendix C: Phase 1 consent for focus group participants

Informed Consent for Participation in Research Activities

*Exploring the influence of Industry 4.0 technology on buyer-supplier relationships and supply chain agility*

Principal Investigator & Interviewer: Honey Zimmerman Phone Number:

**Summary of the Study**

This is a research project conducted by Honey Zimmerman, Doctor of Business Administration student under the supervision of Dr. George Zsidisin at the University of Missouri-St. Louis. Your participation in the study is voluntary. The purpose of this research is to explore the influences of Industry 4.0 (I4.0) technology on buyer-supplier relationships and supply chain agility, if any. This study will involve two phases of data collection. First, through a series of interviews (conducted individually for supplier firms and in focus groups for the buying firm), we seek to gain a better understanding of participants' perceptions about the I4.0 technology, whether it has impacted the inter-organizational relationships, and the technologies' effects on the agility of the firm. From the interviews, we will develop hypotheses to be tested in the second phase. Data for the second phase will come from survey questionnaires completed by participants as part of a matched buyer-supplier dyad. Participants will only be asked to participate in one phase of data collection in order to reduce bias.

1. You are invited to participate in this research study conducted by Honey Zimmerman. You must be at least 18 years old to participate in this study. The purpose of this research is to examine if Industry 4.0 technology influences relationships between

buyer and supplier firms and the agility of the direct supply chain. This study is being conducted as part of the educational requirements of the Doctor of Business Administration program at the University of Missouri-St. Louis. Ultimately, we hope to submit the findings of this project to scientific conferences and journals.

2. Your participation will involve:
   - Participating in a focus group with other individuals from your company that also have direct interaction with suppliers. The interview will last approximately one hour and will be conducted remotely via technology (e.g., Microsoft Teams, Zoom, etc.). The interviewer can help you with the technology if needed.
   - The interview will be audio-recorded, and the audio will be transcribed by a professional transcription company contracted through the UMSL DBA program.
   - You may participate in this study only once. The total amount of time involved in your participation will be approximately one hour.

A maximum of 36 participants across at least two groups may be involved in this focus group interview portion of the research. Participants will include individuals from at least two different facilities from (insert company name).

3. There are minimal risks or discomforts associated with this research. They include potential risks to your professional reputation if you choose to disclose damaging information and loss of confidentiality risk. While we do not believe that the topic of this study is very sensitive, and the information shared will not be attributed to you directly outside of the focus group, you should use your judgment when choosing what types of information to share with the interviewer and other members from your organization within the group.

4. There are no direct benefits for you participating in this study.
5. Your participation is voluntary, and you may choose not to participate in this research study or withdraw your consent at any time. You will NOT be penalized in any way should you choose not to participate or withdraw.
6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication that may result from this study. You will be given a pseudonym (fake name) and will only be described using the pseudonym and demographic information in presentations or publications – we will not use your real name. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection) that would lead to the disclosure of your data as well as any other information collected by the researcher.
7. If you have any questions or concerns regarding this study, or if any problems arise, you may call your interviewer (phone numbers at the top of this form) or the Faculty Advisor, Dr. George Zsidisin (insert phone number here). You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research at 314-516-5899.

## Appendix D: Phase 1 email introduction to suppliers

Hello XXXXXX! My name is Honey Zimmerman, a doctoral candidate at the University of Missouri-St. Louis. XXXXXXX from XXXXXX gave me your contact information. He thought you'd be a great resource to participate in a research project about the influence of Industry 4.0 (I4.0) technology in business. More specifically, I am interested in exploring if the I4.0 technology influences buyer-supplier relationships and the agility of the direct supply chain.

(Insert company name here) is the buying firm in my study, and your organization has been identified as a key supplier. In order to learn more, I would like to interview you remotely using video conferencing technology. If you agree to participate, the interview will last no more than one hour.

To learn more about this topic, I will be asking questions such as:

- Please describe how you use technology to connect and interact with (Insert company name here).
- Which technologies do you find most useful in your interactions with customers?
- Please describe if and how you feel the technology has impacted the relationship with (Insert company name here) over time.

Privacy and confidentiality are very important to us at the University of Missouri-St. Louis, so please be assured your responses in the interview will not be attributed to you (nor your company), and they won't be shared directly with anyone from the buying organization.

Attached to this email is a copy of the consent document for your record. If you are willing to participate in this study, please simply respond to me by (insert date here) to

set up a time that is most convenient for you. If you have any questions or concerns about the information provided, please don't hesitate to contact me via email or call me at (insert phone number here).

## Appendix E: Phase 1 informed consent for supplier interviews

Informed Consent for Participation in Research Activities

*Exploring the influence of Industry 4.0 technology on buyer-supplier relationships and supply chain agility*

Principal Investigator & Interviewer: Honey Zimmerman

**Summary of the Study**

This is a research project conducted by Honey Zimmerman, Doctor of Business Administration student under the supervision of Dr. George Zsidisin at the University of Missouri-St. Louis. Your participation in the study is voluntary. The purpose of this research is to explore the influences of Industry 4.0 (I4.0) technology on buyer-supplier relationships and supply chain agility, if any. This study will involve two phases of data collection. First, through a series of interviews (conducted individually for supplier firms and in focus groups for the buying firm), we seek to gain a better understanding of participants' perceptions about the I4.0 technology, whether it has impacted the inter-organizational relationships, and the technologies' effects on the agility of the firm. From the interviews, we will develop hypotheses to be tested in the second phase. Data for the second phase will come from survey questionnaires completed by participants as part of a matched buyer-supplier dyad. Participants will only be asked to participate in one phase of data collection in order to reduce bias.

1. You are invited to participate in this research study conducted by Honey Zimmerman. You must be at least 18 years old to participate in this study. The purpose of this research is to examine if Industry 4.0 technology influences relationships between buyer and supplier firms and the agility of the direct supply chain. This study is being

conducted as part of the educational requirements of the Doctor of Business Administration program at the University of Missouri-St. Louis. Ultimately, we hope to submit the findings of this project to scientific conferences and journals.

2. Your participation will involve:
   - Participating in a one-on-one interview with the primary investigator as the interviewer. The interview will last approximately one hour and will be conducted remotely via technology (e.g., Microsoft Teams, Zoom, etc.). The interviewer can help you with the technology if needed.
   - The interview will be audio-recorded, and the audio will be transcribed by a professional transcription company contracted through the UMSL DBA program.
   - You may participate in this study only once. The total amount of time involved in your participation will be approximately one hour.

A maximum of 12 participants may be involved in this interview portion of the research. Participants will include individuals from multiple organizations that supply goods and/or services to (Insert Company Name Here).

3. There are minimal risks or discomforts associated with this research. They include potential risks to your professional reputation if you choose to disclose damaging information and loss of confidentiality risk. While we do not believe that the topic of this study is very sensitive, and the information shared will not be attributed to you directly, you should use your judgment when choosing what types of information to share with the interviewer.
4. There are no direct benefits for you participating in this study.

5. Your participation is voluntary, and you may choose not to participate in this research study or withdraw your consent at any time. You will NOT be penalized in any way should you choose not to participate or withdraw.
6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication that may result from this study, nor will the name of your employer. You will be given a pseudonym (fake name) and will only be described using the pseudonym and demographic information in presentations or publications – we will not use your real name. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection) that would lead to the disclosure of your data as well as any other information collected by the researcher.
7. If you have any questions or concerns regarding this study, or if any problems arise, you may call your interviewer (phone numbers at the top of this form) or the Faculty Advisor, Dr. George Zsidisin (insert phone number here). You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research at 314-516-5899.

## Appendix F: Phase 1 interview protocol for the buying firm focus groups

Intro: Thank you for taking the time to participate in this focus group. We are just beginning this project, and I am requesting your help in understanding how you use technology in working with key suppliers, as well as your perceptions on how that technology impacts the relationships with suppliers and the agility of your immediate supply chain.

The purpose of the research is to explore if and how I4.0 technology influences buyer-supplier relationships and firm supply chain agility. By firm supply chain agility, I am referring to the *capability of a firm and its key suppliers and customers to adapt or respond in a timely manner to changes in the marketplace.*

I would like to set some common expectations, which were also outlined in the consent form that you signed. Your personal information will remain confidential at all times. I want to record this discussion so that I can review it as I analyze the information. The original transcript will be stored and password-protected to where only I can access it. The purpose of the recording is only to be sure I do not miss something that was said and will be deleted immediately after transcription. Neither the recordings nor the transcripts will be shared with anyone, and no comments will be attributed to you specifically. I will not use any names of individuals nor companies in this project. Do I have everyone's consent to record this conversation?

As we proceed today, I am going to ask you a question, and I would like you to write down your initial response. Then I will open it up for discussion. The point of having you write it down first is to minimize groupthink. So, at the end, I will ask if anyone wrote down something that was not already discussed.

For our discussion, I would like you to look at this list of technologies, which was also included in the introduction email I sent you. Since these advanced technologies are the focus of my study, I would like you to answer the questions with these in mind as much as possible.

| I.40 technologies |
| --- |
| ▪ Big data analytics |
| ▪ Internet of Things |
| ▪ Artificial intelligence |
| ▪ Autonomous robots |
| ▪ Horizontal & vertical system integration |
| ▪ Mobile technologies |
| ▪ Simulation |
| ▪ Additive manufacturing |
| ▪ The cloud |
| ▪ Augmented reality |
| ▪ RFID and real time location systems (RTLS) |
| ▪ Cyber security |

Are there any questions before we begin?

First, I would appreciate it if each of you would introduce yourself by stating

- your name,
- your current title & location,
- how long you have been with Company XYZ in total, and how long you have served in your current role, and
- a brief description of your current position and scope of interaction with suppliers.

Interview Questions:

1. Please describe how you use technology to connect and interact with key suppliers. Which technologies from the list do you use?
2. How do you think the technology adds value?
3. Which technology do you find the most useful? Why?

4. What do you feel are the biggest barriers to technology implementation with key suppliers? Why?
5. Please describe if and how you feel the technology has impacted supplier relationships.
6. This past year has experienced significant volatility due to the global pandemic. Thinking about the business environment, how do you feel technology influences your organization's ability, along with your key suppliers, to adapt or respond swiftly to changes in the marketplace?

Alternate interview questions:

7. How do you measure successful technology implementation with key suppliers?
8. What technologies are you not utilizing with your suppliers, at all or as much as you would like, that you think would add value to your organization?
9. How do you feel technology has improved your supplier relationships?
10. How do you feel technology has hindered your supplier relationships?
11. How do you feel technology has improved your supply chain agility?
12. How do you feel technology has hindered your ability to respond or adapt to changes in the marketplace?

## Appendix G: Phase 1 interview protocol for the supplier firms

Intro: Thank you for taking the time to participate in this interview. We are just beginning this project, and I am requesting your help in understanding how you use technology in working with Company XYZ, as well as your perceptions on how it impacts the relationships with them and your agility as it relates to Company XYZ.

The purpose of my research is to explore if and how I4.0 technology influences buyer-supplier relationships and firm supply chain agility. By firm supply chain agility, I am referring to the *capability of a firm and its key suppliers and customers to adapt or respond in a speedy manner to changes in the marketplace.*

I would like to set some common expectations, which were also outlined in the consent form that you signed. Your personal information will remain confidential. I want to record this conversation so that I can review it as I analyze the information. The original transcript will be stored and password-protected to where only I can access it. The purpose of the recording is only to be sure I do not miss something that was said, and it will be deleted immediately after transcription. Neither the recordings nor the transcripts will be shared with anyone, and no comments will be attributed to you specifically. I will not use any names of individuals nor companies in this project. Do I have your consent to record this conversation?

Before we begin, I would like you to look at this list of technologies, which was also included in the introduction email I sent you. Since these advanced technologies are the focus of my study, I would like you to answer the questions with these in mind as much as possible.

| I.40 technologies |
| --- |
| ▪ Big data and analytics |

| |
|---|
| ▪ Internet of Things |
| ▪ Artificial intelligence |
| ▪ Autonomous robots |
| ▪ Horizontal & vertical system integration |
| ▪ Mobile technologies |
| ▪ Simulation |
| ▪ Additive manufacturing |
| ▪ The cloud |
| ▪ Augmented reality |
| ▪ RFID and real time location systems (RTLS) |
| ▪ Cyber security |

Do you have any questions before we begin?

First, I'd like you to introduce yourself by stating

- your name,
- the company you work for,
- your current title & location,
- how long you have been with the company, and how long you have been in your current role, and
- a brief description of your current position and scope of interaction with Company XYZ.

Interview Questions:

1. Please describe how you use technology to connect and interact with Company XYZ. Which technologies from the list do you use?
2. How do you think each technology adds value individually?
3. Which technology do you find the most useful? Why?
4. Please describe how you feel technology has impacted the relationships with Company XYZ.
5. This past year has experienced significant volatility due to the global pandemic. Thinking about the business environment, how do you feel technology influenced

your organization's ability, along with Company XYZ, to adapt or respond swiftly to changes in the marketplace?

Alternate interview questions:

6. What technologies are you not utilizing with Company XYZ, at all or as much as you would like, that you think would add value to your organization?
7. How do you feel technology has improved your relationship with Company XYZ?
8. How do you feel technology has hindered your relationship?
9. How do you feel technology has improved your ability to respond or adapt to changes in the marketplace?
10. How do you feel technology has hindered your ability to respond or adapt to changes?

## Appendix H: Phase 2 respondent consent form (used for both sample groups)

Informed Consent for Participation in Research Activities

*Exploring the influence of Industry 4.0 technology on buyer-supplier relationships and supply chain agility*

Principal Investigator & Interviewer: Honey Zimmerman

**Summary of the Study**

This is a research project conducted by Honey Zimmerman, Doctor of Business Administration student under the supervision of Dr. George Zsidisin at the University of Missouri-St. Louis. Your participation in the study is voluntary. The purpose of this research is to explore the influences of Industry 4.0 (I4.0) technology implementation on buyer-supplier relationships and a firm's supply chain agility. Data for this phase of the study will come from survey questionnaires completed by participants as part of an organizational (buyer-supplier) dyad.

1. You are invited to participate in this research study conducted by Honey Zimmerman. You must be at least 18 years old to participate in this study. The purpose of this research is to examine if Industry 4.0 technology influences relationships between buyer and supplier firms and the agility of the direct supply chain. This study is being conducted as part of the educational requirements of the Doctor of Business Administration program at the University of Missouri-St. Louis. Ultimately, we hope to submit the findings of this project to scientific conferences and journals.

2. Your participation in this study will involve:

- Completing a survey questionnaire made up of approximately 40 questions and estimated to take less than 15 minutes to complete.
- The survey will be completed online through Qualtrics software.
- The survey results will be recorded and stored in a password-protected drive.

- The survey does not include personal questions beyond those regarding your work experience and the characteristics of the company you represent.
- You may participate in this study only once. The total amount of time involved in your participation will be approximately 15 minutes.

A maximum of 500 participants will be recruited for the survey. Participants will include individuals from the focal buying firm and its suppliers.

3. There are minimal risks or discomforts associated with this research. While we do not believe that the topic of this study is very sensitive, and the survey responses will not be attributed to you directly, there is a potential loss of confidentiality risk.
4. There are no direct benefits for you participating in this study.
5. Your participation is voluntary, and you may choose not to participate in this research study or withdraw your consent at any time. While completing the survey, if you come to a question that you prefer not to answer, you can skip it and move on to the next question. You will NOT be penalized in any way should you choose not to participate. Participation in the survey signifies your consent. You have the right to withdraw your consent at any time by not completing the survey or request by email afterward to have your response withdrawn if you have already completed the survey.
6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication that may result from this study. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection) that would lead to the disclosure of your data as well as any other information collected by the researcher.
7. If you have any questions or concerns regarding this study, or if any problems arise, you may call your interviewer (phone numbers at the top of this form) or the Faculty Advisor, Dr. George Zsidisin (insert phone number here). You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research at 314-516-5899.

## Appendix I: Phase 2 buyer survey

**Start of Block: Introduction**

1. This survey is confidential. Your participation is voluntary, and if you come to a question that you prefer not to answer, you can skip it and move on to the next question. A description of consent is attached. Participation in the survey signifies your consent. You have the right to withdraw your consent at any time by not completing the survey or request by email afterward to have your responses withdrawn if you have already completed the survey (using the unique code given at the end of the survey). This survey will not be used to monitor performance or behavior. This research is part of my final requirements for the Doctor of Business Administration Program at the University of Missouri-St. Louis, and therefore, I am an impartial party on this quest. If you have any questions, please contact me at hmzw5q@umsystem.edu.

Is this your first time taking this survey? *(1) Yes, (2) No*

*If you are completing this more than once, you will only be asked to complete QUESTIONS #25-33 regarding a specific supplier.*

**End of Block: Introduction**

**Start of Block: Descriptive Information**

Q1 Which of the following most closely describes your current position within Company XYZ?

*(1) Procurement/supply management/sourcing, (2) supplier development/supplier relationship management, (3) cost engineer, (4) other*

Q2 From which country are you primarily based?

*(1) Germany, (2) United States, (3) Brazil, (4) Canada, (5) Mexico, (6) A European country other than Germany, (7) Other (non-European country)*

Q3 Approximately how long have you worked for Company XYZ?

*(1) Less than 2 years, (2) 2 to 5 years, (3) 6 to 10 years, (4) 11 to 15 years, (5) 16 years or more*

**End of Block: Descriptive Information**

**Start of Block: Section 1 Intro**

Q4 *The following questions will reference stakeholders. A stakeholder is defined as any group or individual who can affect or is affected by the achievement of a corporation's purpose. Stakeholders include employees, customers, suppliers, stockholders, banks, environmentalists, government and other groups who can help or hurt the corporation." (Freeman, 1984, p. vi)*

**End of Block: Section 1 Intro**

**Start of Block: Section 1**

*For Q4-Q10, (1) Strongly agree, (2) Agree, (3) Somewhat agree, (4) Neither agree nor disagree, (5) Somewhat disagree, (6) Disagree, (7) Strongly disagree*

Q4 Our firm is willing to explain its decisions to stakeholders.

Q5 Our firm wants to understand how its decisions affect stakeholders.

Q6 Our firm wants to be accountable to stakeholders for its actions.

Q7 Our firm asks for feedback from stakeholders about the quality of its information.

Q8 Our firm provides detailed information to stakeholders.

Q9 Our firm makes it easy to find the information stakeholders need.

Q10 Our firm takes time with stakeholders to understand their needs.

**End of Block: Section 1**

**Start of Block: Section 2**

*For Q11-Q24, (1) strongly agree, (2) somewhat agree, (3) neither agree nor disagree, (4) somewhat disagree, (5) strongly disagree*

Q11 Our firm can swiftly deal with threats in our environment.

Q12 Our firm can quickly respond to changes in the business environment.

Q13 Our firm can rapidly address opportunities in our environment.

Q14 When needed, our firm can adjust our supply chain operations to the extent necessary to execute our decisions.

Q15 Our firm can increase its short-term capacity as needed.

Q16 Our firm can adjust the specification of orders as requested by our customers.

Q17 Our firm can promptly identify opportunities in its environment.

Q18 Our firm can rapidly sense threats in its environment.

Q19 Our firm can quickly detect changes in our environment.

Q20 Our firm always receives the information we demand from our suppliers.

Q21 Our firm always obtains the information we request from our customers.

Q22 Our firm can make definite decisions to address opportunities in our environment.

Q23 Our firm can make concrete decisions to respond to threats in its environment.

Q24 Our firm can make resolute decisions to deal with changes in its environment.

**End of Block: Section 2**

**Start of Block: Section 3**

Q25-33

The following questions reference "this supplier." Please select a key supplier you are

familiar with to focus on for this portion of the survey. A "key supplier" is one that is considered strategic to the operations of Company XYZ. The supplier can be an indirect or direct provider of goods or services.

At the end of this survey, you will be provided with a randomly generated code, which will be used to match your response with that of the supplier for analysis while still maintaining anonymity. To work correctly, upon completion of this survey, please send the unique supplier code and the link for the corresponding supplier survey to the supplier you selected for this portion.

Q25 How many years has Company XYZ worked with this supplier?

0 5 10 15 20 25 30 35 40 45 50

Round to the nearest whole year ()

*For Q26-Q33, (1) Strongly agree, (2) Agree, (3) Somewhat agree, (4) Neither agree nor disagree, (5) Somewhat disagree, (6) Disagree, (7) Strongly disagree*

Q26 This supplier *provides* Company XYZ with operational plans (e.g., distribution plan, production plan) regarding the products they produce for us.

Q27 This supplier *provides* Company XYZ with detailed product design information.

Q28 This supplier *collects* operations information (e.g., batch size, run quality, transfer quality, buffer stock, available machines, machine breakdown time).

Q29 This supplier *shares* operations information with Company XYZ.

Q30 This supplier *collects* planning and design information (e.g., current performances of operations level, resource utilization, rework and scrap level, level of work in progress).

Q31 This supplier *shares* planning and design information with Company XYZ.

Q32 This supplier *collects* strategic information (e.g., current performances of planning and design level, new order, product demand, internal and external expertise, teachability, culture, government regulations).

Q33 This supplier *shares* strategic information with Company XYZ.

**End of Block: Section 3**

**Start of Block: Section 4 intro**

Q34-38

The final five questions relate to the four base technologies of Industry 4.0, which include:

**Internet of Things (IoT)** refers to "a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."

Source: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

**The cloud** refers to "servers that are accessed over the Internet, and the software and databases that run on those servers. Cloud servers are located in data centers all over the world. By using cloud computing, users and companies don't have to manage physical servers themselves or run software applications on their own machines." Source: https://www.cloudflare.com/learning/cloud/what-is-the-cloud/

**Big data** includes many types of data including, but not limited to: "(1) traditional enterprise data, (2) machine-generated/sensor data (e.g., weblogs, smart meters, manufacturing sensors, equipment logs) and (3) social data" (Opresnik & Taisch, 2015)

**Big data analysis** "involves the data storage, management, analysis, and visualization of very large and complex datasets" (Russom, 2011) and "consists of an expansive collection of data (large volumes) that are updated quickly and frequently (high velocity) and that exhibit a huge range of different formats and content (wide variety)" (Davis, 2014)

**End of Block: Section 4 intro**

**Start of Block: Section 4**

Q34 Has your company adopted at least one of the following technologies: cloud services, big data, big data analytics, or Internet of Things (IoT)? (1) Yes, (2) No

*If yes to Q34, Q35-Q38: (1) not yet implemented, (2) low implementation, (3) medium implementation, (4) high implementation, (5) advanced implementation*

Q35 (IF Yes to Q34) In your opinion, what is the current level of implementation at your firm regarding the use of **cloud services**?

Q36 (IF Yes to Q34) In your opinion, what is the current level of implementation at your firm regarding the **collection of big data**?

Q37 (IF Yes to Q34) In your opinion, what is the current level of implementation at your firm regarding the use of **big data analytics?**

Q38 (IF Yes to Q34) In your opinion, what is the current level of implementation at your firm regarding the use of the **Internet of Things (IoT)**?

*If no to Q34, Q35-Q38: (1) no plans to implement that I am aware of, (2) plans to implement in the next 5 years, (3) plans to implement in the next 3 years, (4) plans to implement in the next year, (5) already implemented this technology.*

Q35 (IF No to Q34) Please indicate the extent to which your organization is planning to implement **cloud services** by completing this sentence: Our firm has

Q36 (IF No to Q34) Please indicate the extent to which your organization is planning to implement the **collection of big data** by completing this sentence: Our firm has

Q37 (IF No to Q34) Please indicate the extent to which your organization is planning to implement **big data analytics** by completing this sentence: Our firm has

Q38 (IF No to Q34) Please indicate the extent to which your organization is planning to implement the **Internet of Things (IoT)** by completing this sentence: Our firm has

**End of Block: Section 4**

**Start of Block: Instructions for supplier referral**

For questions 25 through 33, you selected a key supplier to focus on while answering that portion of the survey. Please copy and paste the unique supplier code and the link for the corresponding supplier survey below and send it to your contact at that supplier firm to request their participation.

**Please share this code and survey link with the supplier:**

**Unique supplier code: ${e://Field/RandomID}**

Supplier Survey Link

**End of Block: Instructions for supplier referral**

**End of Survey**

Thank you for taking the survey. Your response has been recorded.

There is just one more important step!

Please email the supplier survey link and unique supplier code previously provided to your contact at the supplier firm. Here it is again for your convenience:

Unique supplier code: ${e://Field/RandomID}

Supplier Survey Link

Here is a note you are welcome to use (in part or in whole) in that email requesting their participation:

*Please consider participating in a survey about buyer-supplier relationships. Company XYZ is the focal firm in this study as the customer, so your perspective from the supplier's side of the relationship will help to reach the goal of the research.*

*Honey Zimmerman, a doctoral student at the University of Missouri-St. Louis, is conducting research to understand the effects of technology and information transparency on a firm's agility within the supply chain. The goal is to provide insight into the value of technology and information exchange within a buyer-supplier relationship.*

*We feel this research on agility is particularly important right now, given the supply chain challenges brought on by the global pandemic. If you are willing to complete a short questionnaire, which should only take about 15 minutes and can be done from a mobile device, simply click on the link below and use the unique supplier code to begin.*

## Appendix J: Phase 2 supplier survey

**Start of Block: Introduction & Consent**

The survey is confidential. Your participation is voluntary, and if you come to a question that you prefer not to answer, you can skip it and move on to the next question. A description of consent is attached. Participation in the survey signifies your consent. You have the right to withdraw your consent at any time by not completing the survey or request by email afterward to have your responses withdrawn if you have already completed the survey (referencing the unique supplier code). This survey will not be used to monitor performance or behavior. This research is part of my final requirements for the Doctor of Business Administration Program at the University of Missouri-St. Louis, and therefore, I am an impartial party on this quest. If you have any questions, please contact me at (insert).

I. The purpose of the unique supplier code (given to you by the individual at Company XYZ) is to enable matching the responses of buyers and suppliers while maintaining anonymity. Please re-enter the unique supplier code here:

**End of Block: Introduction & Consent**

**Start of Block: Descriptive Information**

Q1 Which of the following most closely describes your current position within your company?

*(1) Customer Service/Account Representative, (2) General Manager, (3) Sales Manager, (4) Other*

Q2 Is your company a subsidiary of a larger parent company? *(1) Yes, (2) No*

Q3 (If no to Q2)Approximately how many employees does your organization employ across all locations?

*(1) Less than 50, (2) Less than 250, (3) Less than 500, (4) Less than 1000, (5) 1000+*

Q3 (If yes to Q2) Approximately how many employees does your organization (only the subsidiary) employ across all locations?

*(1) Less than 50, (2) Less than 250, (3) Less than 500, (4) Less than 1000, (5) 1000+*

Q4 (If yes to Q2) Approximately how many employees does your parent company employ across all locations?

*(1) Less than 5,000, (2) 5,000 to 10,000, (3) More than 10,000*

Q5 (If yes to Q2) What is the home country of your parent company? (Please do not enter personal data)

Q4 (If no to Q2) What is the home country of your company? (Please do not enter personal data)

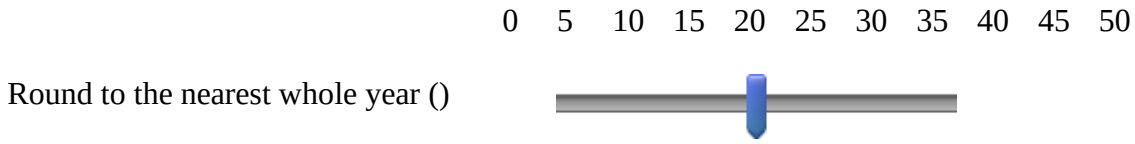
Q5 (If no to Q2) From which country of operation are you primarily based?

*(1) United States, (2) Germany, (3) Brazil, (4) Canada, (5) Mexico, (6) Other European country, (7) Other non-European country*

Q6 Select the following industry sectors to which you supply goods/services (select all that apply)

*(1) Aerospace, (2) Automotive, (3) Consumer Goods, (4) Energy, (5) Healthcare, (6) Industrial, (7) Information technology and/or telecommunications, (8) Other*

Q7 How many years has your organization worked with Company XYZ as a customer?




**End of Block: Descriptive Information**

**Start of Block: Section Intro**

*The following questions will reference stakeholders. A stakeholder is defined as any group or individual who can affect or is affected by the achievement of a corporation's purpose. Stakeholders include employees, customers, suppliers, stockholders, banks, environmentalists, government and other groups who can help or hurt the corporation." (Freeman, 1984, p. vi)*

**End of Block: Section Intro**

**Start of Block: Section 1**

*For Q8-Q22: (1) Strongly agree, (2) Agree, (3) Somewhat agree, (4) Neither agree nor disagree, (5) Somewhat disagree, (6) Disagree, (7) Strongly disagree*

Q8 Our firm is willing to explain its decisions to stakeholders.

Q9 Our firm wants to understand how its decisions affect stakeholders.

Q10 Our firm wants to be accountable to stakeholders for its actions.

Q11 Our firm asks for feedback from stakeholders about the quality of its information.

Q12 Our firm provides detailed information to stakeholders.

Q13 Our firm makes it easy to find the information stakeholders need.

Q14 Our firm takes time with stakeholders to understand their needs.

**End of Block: Section 1**

**Start of Block: Section 2**

Q15 Our firm *provides* Company XYZ with operational plans (e.g., distribution plan, production plan) regarding the products they buy from us.

Q16 Our firm *provides* Company XYZ with detailed product design information.

Q17 Our firm *collects* operations information (e.g., batch size, run quality, transfer quality, buffer stock, available machines, machine breakdown time).

Q18 Our firm *shares* operations information with Company XYZ.

Q19 Our firm *collects* planning and design information (e.g., current performances of operations level, resource utilization, rework and scrap level, level of work in progress).

Q20 Our firm *shares* planning and design information with Company XYZ.

Q21 Our firm *collects* strategic information (e.g., current performances of planning and design level, new order, product demand, internal and external expertise, teachability, culture, government regulations).

Q22 Our firm *shares* strategic information with Company XYZ

**End of Block: Section 2**

**Start of Block: Section 3**

*For questions Q23-Q36: (1) strongly agree, (2) somewhat agree, (3) neither agree nor disagree, (4) somewhat disagree, (5) strongly disagree*

Q23 Our firm can swiftly deal with threats in our environment.

Q24 Our firm can quickly respond to changes in the business environment.

Q25 Our firm can rapidly address opportunities in our environment.

Q26 When needed, our firm can adjust our supply chain operations to the extent necessary to execute our decisions.

Q27 Our firm can increase its short-term capacity as needed.

Q28 Our firm can adjust the specification of orders as requested by our customers.

Q29 Our firm can promptly identify opportunities in its environment.

Q30 Our firm can rapidly sense threats in its environment.

Q31 Our firm can quickly detect changes in our environment.

Q32 Our firm always receives the information we demand from our suppliers.

Q33 Our firm always obtains the information we request from our customers.

Q34 Our firm can make definite decisions to address opportunities in our environment.

Q35 Our firm can make concrete decisions to respond to threats in its environment.

Q36 Our firm can make resolute decisions to deal with changes in its environment.

**End of Block: Section 3**

**Start of Block: Section 4 intro**

The final five questions relate to the four base technologies of Industry 4.0, which include:

**Internet of Things (IoT)** refers to "a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."

Source: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

**The cloud** refers to "servers that are accessed over the Internet, and the software and databases that run on those servers. Cloud servers are located in data centers all over the world. By using cloud computing, users and companies don't have to manage physical servers themselves or run software applications on their own machines." Source: https://www.cloudflare.com/learning/cloud/what-is-the-cloud/

**Big data** includes many types of data including, but not limited to: "(1) traditional enterprise data, (2) machine-generated/sensor data (e.g., weblogs, smart meters, manufacturing sensors, equipment logs) and (3) social data" (Opresnik & Taisch, 2015)

**Big data analysis** "involves the data storage, management, analysis, and visualization of very large and complex datasets" (Russom, 2011) and "consists of an expansive collection of data (large volumes) that are updated quickly and frequently (high velocity) and that exhibit a huge range of different formats and content (wide variety)" (Davis, 2014)

**End of Block: Section 4 intro**

**Start of Block: Section 4**

Q37 Has your company adopted at least one of the following technologies: cloud services, big data, big data analytics, or the Internet of Things (IoT)? (1) Yes or (2) No

*If yes to Q37, Q38-Q41: (1) not yet implemented, (2) low implementation, (3) medium implementation, (4) high implementation, (5) advanced implementation*

Q38 (If yes to Q37) In your opinion, what is the current level of implementation at your firm regarding the use of **cloud services**?

Q39 (If yes to Q37) In your opinion, what is the current level of implementation at your firm regarding the **collection of big data**?

Q40 (If yes to Q37) In your opinion, what is the current level of implementation at your firm regarding the use of **big data analytics**?

Q41 (If yes to Q37) In your opinion, what is the current level of implementation at your firm regarding the use of **the Internet of Things (IoT)**?

*If no to Q37, Q38-Q41: (1) no plans to implement that I am aware of, (2) plans to implement in the next 5 years, (3) plans to implement in the next 3 years, (4) plans to implement in the next year, (5) already implemented this technology.*

Q38 (If no to Q37) Please indicate the extent to which your organization is planning to implement **cloud services** by completing this sentence: Our firm has…

Q39 (If no to Q37) Please indicate the extent to which your organization is planning to implement the **collection of big data** by completing this sentence: Our firm has…

Q40 (If no to Q37) Please indicate the extent to which your organization is planning to implement **big data analytics** by completing this sentence: Our firm has…

Q41 (If no to Q37) Please indicate the extent to which your organization is planning to implement the **Internet of Things (IoT)** by completing this sentence: Our firm has…

**End of Block: Section 4**

**End of Survey**

Thank you for taking the time to take this survey.

Your responses have been recorded.

## Appendix K: Independent samples t-test results

| Dependent variable | Data sample | Group 1 | Group 2 | Accept/Reject Null Hypotheses that the means are equal | Result if difference detected |
|---|---|---|---|---|---|
| Firm Supply Chain Agility | Buyer | Americas | Non-Americas | Reject | M1=2.2610, SD1=.34665<br>M2=1.7940, SD2=.60716<br>t (94.24)= -4.875, p<.001<br>Cohen's d = .539 |
| | | European | Non-European | Accept | |
| | | Other | Non-Other | Accept | |
| | | I4.0 Adoption | No I4.0 Adoption | Accept | |
| Supplier Transparency | Buyer | Americas | Non-Americas | Accept | |
| | | European | Non-European | Accept | |
| | | Other | Non-Other | Accept | |
| | | I4.0 Adoption | No 14.0 Adoption | Accept | |
| I4.0 technology adoption | Buyer | Americas | Non-Americas | Accept | |
| | | European | Non-European | Accept | |
| | | Other | Non-Other | Accept | |
| Firm Supply Chain Agility | Supplier | Americas Operations | Non-Americas Operations | Accept | |
| | | European Operations | Non-European Operations | Accept | |
| | | Other Operations | Non-Other Operations | Reject | M1=1.99, SD1=1.3199<br>M2=2.2829, SD2=1.2469<br>t(62)=2.836, p=.006<br>Cohen's d = .727 |
| | | I4.0 Adoption | No 14.0 Adoption | Accept | |
| | | SME | Non-SME | Reject | M1=1.8829, SD1=.45122<br>M2=1.6567, SD2=.42008<br>t(62)=-2.039, p=.046<br>Cohen's d = -.516 |
| | | Americas Ownership | Non-Americas Ownership | Accept | |
| | | European Ownership | Non-European Ownership | Accept | |
| | | Asia/Pacific Ownership | Non-Asia/Pacific Ownership | Reject | M1=1.6585, SD1=.40178<br>M2=1.9013, SD2=.46371<br>t(62)=2.223, p=.030<br>Cohen's d = .557 |
| | | Subsidiary | Non-Subsidiary | Accept | |
| | | Aerospace | Non-Aerospace | Accept | |
| | | Industrial | Non-Industrial | Accept | |
| | | Energy | Non-Energy | Accept | |

| Dependent variable | Data sample | Group 1 | Group 2 | Accept/Reject Null Hypotheses that the means are equal | Result if difference detected |
|---|---|---|---|---|---|
| | | Consumer Goods | Non-Consumer Goods | Accept | |
| | | Healthcare | Non-Healthcare | Accept | |
| | | IT/Telecom | Non-IT/Telecom | Accept | |
| Supplier Transparency | Supplier | Americas Operations | Non-Americas Operations | Accept | |
| | | European Operations | Non-European Operations | Accept | |
| | | Other Operations | Non-Other Operations | Accept | |
| | | I4.0 Adoption | No 14.0 Adoption | Accept | |
| | | SME | Non-SME | Reject | M1=2.1910, SD1=.59989<br>M2=1.8424, SD2=.11189<br>t(62)=-2.326, p=.023<br>Cohen's d = -.589 |
| | | Americas Ownership | Non-Americas Ownership | Reject | M1=2.3867, SD1=.62447<br>M2=1.9390, SD2=.57517<br>t(62)=-2.586, p=.012<br>Cohen's d = -.763 |
| | | European Ownership | Non-European Ownership | Accept | |
| | | Asia/Pacific Ownership | Non-Asia/Pacific Ownership | Accept | |
| | | Subsidiary | Non-Subsidiary | Accept | |
| | | Aerospace | Non-Aerospace | Accept | |
| | | Industrial | Non-Industrial | Accept | |
| | | Energy | Non-Energy | Reject | M1=1.7519, SD1=.6122<br>M2=2.1582, SD2=.5799<br>t(62)=2.482, p=.016<br>Cohen's d = .690 |
| | | Consumer Goods | Non-Consumer Goods | Accept | |
| | | Healthcare | Non-Healthcare | Accept | |
| | | IT/Telecom | Non-IT/Telecom | Accept | |
| I4.0 Technology Implementation | Supplier | Americas Operations | Non-Americas Operations | Accept | |
| | | European Operations | Non-European Operations | Accept | |
| | | Other Operations | Non-Other Operations | Accept | |
| | | SME | Non-SME | Accept | |

| Dependent variable | Data sample | Group 1 | Group 2 | Accept/Reject Null Hypotheses that the means are equal | Result if difference detected |
|---|---|---|---|---|---|
| | | Americas Ownership | Non-Americas Ownership | Accept | |
| | | European Ownership | Non-European Ownership | Accept | |
| | | Asia/Pacific Ownership | Non-Asia/Pacific Ownership | Accept | |
| | | Subsidiary | Non-Subsidiary | Reject | M1=2.5250, SD1=1.1714<br>M2=1.8409, SD2=1.2927<br>t(61)=2.193, p=.032<br>Cohen's d = .553 |
| | | Aerospace | Non-Aerospace | Accept | |
| | | Industrial | Non-Industrial | Reject | M1=2.4722, SD1=1.2884<br>M2=1.7593, SD2=1.155<br>t(61)=-2.271, p=.027<br>Cohen's d = 1.2333 |
| | | Energy | Non-Energy | Reject | M1=2.75, SD1=1.1145<br>M2=1.9511, SD2=1.2722<br>t(61)=-2.283, p=.026<br>Cohen's d = -.648 |
| | | Consumer Goods | Non-Consumer Goods | Accept | |
| | | Healthcare | Non-Healthcare | Accept | |
| | | IT/Telecom | Non-IT/Telecom | Accept | |