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Implications of the Internet of Things for the Small and Medium Sized Business

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To the Graduate Council:

I am submitting herewith a thesis written by Amanda Marie Smart entitled "Implications of the Internet of Things for the Small and Medium Sized Business." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

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Implications of the Internet of Things for the Small and Medium Sized Business

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Abstract

The Internet of Things (IoT) is the network of physical objects containing the embedded capability to interact, communicate, and otherwise exchange data with one another and the external environment over a network without human intervention. As the Internet of Things begins to grow into almost all aspects of business, the small to midsize business (SMB) must not get behind. Some unanswered questions include: How will small and medium-sized businesses (SMB) participate in IoT? Have they already begun participating and what challenges have they encountered along the way? Do smaller organizations have a disadvantage compared to larger organizations in the IoT landscape? A literature review and a survey of owners, executives and employees of SMBs were performed in order to gain a better understanding of the current state of awareness and use of IoT technologies. The thesis concludes with a theoretical recommended implementation plan that combines the literature on the strengths and weaknesses of the SMB with the results of the survey as well as the literature examining the challenges and opportunities of IoT into a series of recommendations for implementation. These recommendations are given in the form of a "Maturity Model" that will cover the steps from infancy to a fully mature implementation of IoT solutions.

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Chapter 1: Introduction

1.1 What is the Internet of Things?

The term Internet of Things was coined in 1999 by Kevin Ashton in a presentation he created to discuss RFID at Proctor and Gamble (Ashton). His intention for the term was to describe a new world in which the computer was no longer dependent on humans to interact with the environment. The Internet of Things is often described as yet another phase of the internet or the World Wide Web. The first phases of the internet connected people to networks, people to their data, and people to other people. This new stage, the Internet of Things (IoT), is connecting everything to everything. Cisco later coined another term to describe the phenomenon, the Internet of Everything (IoE). "The IoE brings together the people, processes, data, and things that make networked connections more relevant by turning information into actions." (Kranz, 2017) In order to complete this statement with the full intent of the original definition, one might add that the information is turned into action *without* human intervention, highlighting the key benefit from this advancement. For the purpose of this paper, the following definition will be used: The Internet of Things is the network of physical objects containing the embedded capability to interact, communicate, and otherwise exchange data with one another and the external environment over a network without human intervention.

Like personal computing, the World Wide Web, Lean Manufacturing, Six Sigma and other major drivers that have influenced industry in the last several decades, the Internet of Things will change everything about the way we do business. And just like the movements preceding it, the IoT has crept into industry in incremental stages and often in isolated environments. Figure 1.1 outlines the evolution of IoT technology in industry.

Table 1. Evolution of key IoT technologies

	Before 2010	2010–2015	2015–2020	Beyond 2020
Network	• Sensor networks	• Self-aware and self-organizing networks • Sensor network location transparency • Delay-tolerant networks • Storage networks and power networks • Hybrid networking technologies	• Network context awareness	• Network cognition • Self-learning, self-repairing networks
Software and Algorithms	• Relational database integration • IoT-oriented RDBMS • Event-based platforms • Sensor middleware • Sensor networks middleware • Proximity/ Localization algorithms	• Large-scale, open semantic software modules • Composable algorithms • Next generation IoT-based social software • Next generation IoT-based enterprise applications	• Goal-oriented software • Distributed intelligence, problem solving • Things-to-Things collaboration environments	• User-oriented software • The invisible IoT • Easy-to-deploy IoT software • Things-to-Humans collaboration • IoT 4 All
Hardware	• RFID tags and some sensors • Sensors built into mobile devices • NFC in mobile phones • Smaller and cheaper MEMs technology	• Multiprotocol, multistandards readers • More sensors and actuators • Secure, low-cost tags (e.g., Silent Tags)	• Smart sensors (biochemical) • More sensors and actuators (tiny sensors)	• Nanotechnology and new materials
Data Processing	• Serial data processing • Parallel data processing • Quality of services	• Energy, frequency spectrum-aware data processing • Data processing context adaptable	• Context aware data processing and data responses	• Cognitive processing and optimization

Source: Adapted from Sundmaeker, Guillemin, Friess, and Woelfflé (2010, p. 74)

Figure 1.1: Evolution of key IoT technologies (Lee & Lee, 2015)

Early examples of IoT with varying levels of success include ATMs, POS retail networks, RFID tags, M2M networks in manufacturing, and connected sensors for utility companies. These early adoption examples differ from the future of IoT in that they ran on limited connections with limited devices, applications, and functions while operating on proprietary protocols rather than the more accessible IP or the cloud (Kranz, 2017). Unlike preceding industry movements, the IoT has the ability to converge the silos of business, such that no branch is isolated from the whole. In the perfect IoT environment, a company can make near real-time decisions in response to rapid changes in the market or other stakeholder demands and every branch of the operation will immediately fall in line. Figure 1.1 outlines the evolution of key IoT technologies.

The essential technologies for successful IoT products and services include: RFID, WSN, Middleware, Cloud Computing and IoT application software (Lee & Lee, 2015) Drivers for the IoT include: Bring your own device to work (BYOD), development of low cost sensors, adoption of social media, increasing number of internet users, increasing availability of mobile apps, lower computing and storage costs, pervasiveness of high-speed networks, cloud computing, increasing volumes of data (e.g. Big Data), and new types of connected devices (Bradley, Loucks, Macaulay, & Noronha, 2013).

In 2011, the number of interconnected devices surpassed the population (Evans, 2011) Currently, Gartner estimates that as of 2017 there are 8.4 billion connected devices ranging from smartphones to egg trays. Over the last few years, several research firms have predicted that up to 80 billion devices will be connected by 2025. More recently, in the first and second quarter of 2017, the same firms have reduced these to still staggering, but more modest estimates (Nordrum, 2016). Gartner estimates that the number of connected devices in the world will exceed 20 billion by 2020, an almost 150% increase from 2017. Figure 1.2 summarizes Gartner's estimates.

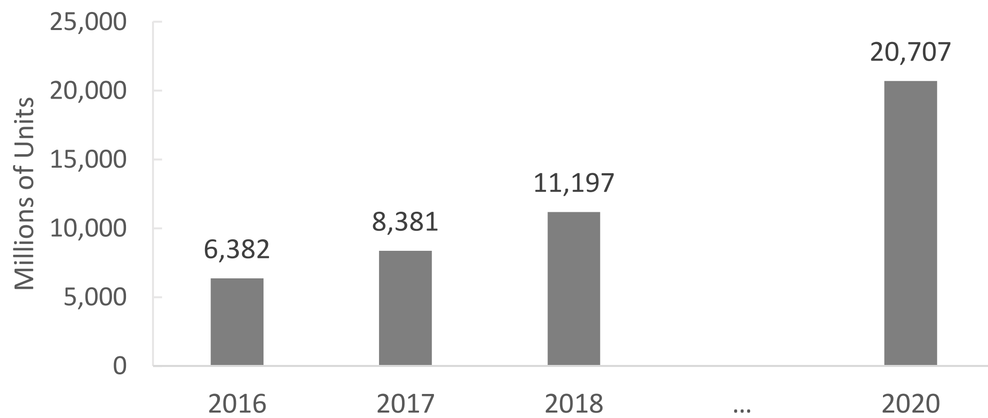

Figure 1.2: Internet of things Units Installed Base by Category (Gartner, 2017)

The research firm IDC has predicted that the global IoT market will reach $7.1 trillion by 2020. McKinsey Global Institute made a prediction that the value could hit $11 trillion annually by 2025, a sum that represents over half of U.S. economic output in a year. Gartner again makes a more modest prediction shown in Figure 1.3 below of almost $3 trillion in spending by 2020.

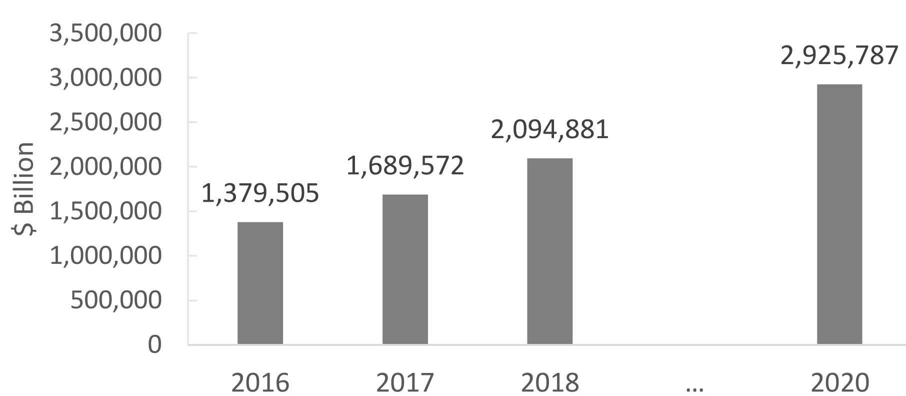

Figure 1.3: IoT Endpoint Spending by Category (Gartner, 2017)

Kranz managed to summarize the overwhelming magnitude of the Internet of Things quite effectively. “Now imagine what’s possible when you can connect anything with anything – production lines with parts and components, production lines with suppliers, products with service providers, logistics operations with transportation companies – and you can do it in near—real time. Designers could create products people really want and use, marketers could sell those products the way people want them, and service and support teams would know where potential problems are and address them before things break. Costs could be contained, and customer satisfaction would soar.” (Kranz, 2017)

1.2 Problem Definition

As the Internet of Things begins to grow into almost all aspects of business, the small to midsize business (SMB) must not get behind. Unlike their larger counterparts, SMBs more heavily rely on innovation for success, therefore it is even more important for them to not only remain current and engage in the Internet of Things landscape but to innovate and participate in growing new applications and technologies (Boer & Gertsen, 2003). For the purposes of this paper, a business with 100 or fewer employees will be considered small, while one with 100-999 employees will be considered to be medium-sized. According to the latest US census data, just over 89% of all US businesses have fewer than 20 employees. This further highlights the fact that a better understanding must be developed regarding how these businesses will participate in the Internet of Things as it remains one of most economically impactful movements of the last ten years. The question now remains, as the Internet of Things becomes an unstoppable force in the market, how will small and medium-sized businesses (SMB) participate? Have they already begun participating and what challenges have they encountered along the way? This thesis hopes to give a current answer to some of these questions, as the popularity of IoT increases rapidly such that continual surveillance is needed to accurately address the present needs of the SMB.

1.3 Research Objectives

This research attempts to answer the following questions qualitatively through literature search and by conducting a survey of small to medium-sized business owners, executives, and other concerned employees.

1) Is IoT relevant and useful for the small to medium sized business? How is it useful?
2) How do small to medium sized businesses perceive IoT?
3) What are the barriers to entry? What are the perceived barriers to entry?
4) Is awareness a barrier to the adoption of IoT technologies in SMBs?

In addition, the following secondary questions are considered qualitatively and incorporated into the recommendations made in the final chapter.

5) Are small to medium sized businesses at a disadvantage, compared to larger corporations?
6) What are the innate characteristics of a small to medium-sized business?
7) How do these characteristics give advantage or disadvantage in the new Industry 4.0?
8) How might a SMB overcome their weaknesses and utilize their strengths to begin the business transformation required to incorporate IoT technologies?

Chapter 1 includes the introduction and objectives for this research. Chapter 2 summarizes a literature search. Chapter 3 outlines the survey conducted and Chapter 4 presents the results of that survey. Finally, Chapter 5 outlines a recommended model for the implementation of IoT in a SMB, in an attempt to contribute an answer to the secondary research questions in the list above. Chapter 6 concludes the research and proposes further research direction.

Chapter 2: Literature Review

2.1 Key Terms

2.1.1 Smart Manufacturing

The Internet of Things is launching the U.S. and other governments and industry around the world into an evolutionary environment full of opportunity. In the U.S., this environment is described by the terms Smart Manufacturing, Advanced Manufacturing or the Industrial Internet, and in Europe, it is Industry 4.0. Shrouf, Ordieres, and Miragliotta describe Industry 4.0 as sustainable, flexible in production volume and customization, and extensively integrated with customers, companies, and suppliers (Shrouf, Ordieres, & Miragliotta, 2014). Herman et al. identified four design principles of the Industry 4.0 (Hermann, Pentek, & Otto, 2016):

1) Interconnection or Interoperability

   The capability of devices, sensors, and people to communicate with each other via the Internet of Things (IoT) and the Internet of People (IoP), combining to form the Internet of Everything (IoE)

2) Information transparency

   The ability of information systems to create a "virtual copy of the physical world" by transforming raw sensor data into real-time context-aware information, ready for interpretation and use.

3) Technical assistance

   The support of human decision making through assistance systems that aggregate and visualize data comprehensibly.

4) Decentralized decisions

   The enabling of autonomous decision making at the lowest possible level.

2.1.2 Cloud Manufacturing

Many terms are being utilized in the research community as it relates to the Internet of Things and its application in manufacturing, one of the most prevalent being Cloud Manufacturing (CMfg). CMfg integrates cloud computing, IoT, virtualization, service-oriented technologies and artificial intelligence by encapsulating all manufacturing resources and capabilities as cloud services (Tao, et al., 2015).

2.1.3 Ubiquitous computing

Ubiquitous computing is a software engineering term used to describe when computing is made to appear anytime and everywhere. The Internet of Things is a more specific application of this term when it involves physical objects.

2.1.4 M2M

The final key term to understand is M2M or Machine to Machine technology, as its definition, purpose and function can often be confused with that of the Internet of Things. M2M is the ability to connect objects with sensors, and even have these objects speak to one another and make autonomous decisions without human intervention. The Internet of Things is an umbrella under which several M2M systems that were developed separately can be brought together to provide new insights. M2M systems typically rely on point-to-point communications with embedded hardware on cellular or wired networks. IoT solutions reply on IP-based networks that can integrate data from multiple sources in a cloud or middleware platform. For example, a manufacturing facility might monitor its machinery for temperature and other factors in order to predict failure and schedule maintenance. However, when these readings can be incorporated with quality control data, process flows, and other data centers, they begin to provide an enterprise-level value.

2.2 Opportunities

2.2.1 Remote Monitoring and Control

One of the more rapidly adopted applications of the IoT is in the area of remote monitoring. Remote monitoring had its beginnings well before its association with the IoT. Public utilities, including electric grids and wastewater purification plants, utilized Remote Terminal Units (RTU) that operated on LAN lines or over telephone wires and were simple alert mechanisms that indicated a system had failed or was near failure (Cramer, 2014). Early remote monitoring technology primarily provided historical performance data rather than real-time, actionable data. With the introduction of innovative data capturing and analysis as well as the IoT, remote monitoring is evolving into a system that not only produces equipment status and minor predictions, but is able to make corrections without human intervention. The ability to collect and utilize large amounts of data real time to make field corrections is radical enough, however the data collected can also be used to perform analytics beyond the traditional uptime of individual machines. Modern, innovative uses of the data allow machines to be analyzed in the context of operations as a whole. A simpler implementation of this strategy would involve a machine sensing failure and triggering maintenance processes autonomously rather than relying on unreliable physical inspections and inspection reports (Lopez Research LLC, 2014). Proactive maintenance could be greatly enhanced by the application of IoT technology and methods. Harley-Davidson made good use of IoT at one of their motorcycle plants by installing a software that not only tracked equipment vitals, such as fan speed, but was able to automatically adjust the equipment if and when a measurement had deviated from an acceptable range (Lopez Research LLC, 2014). Already, in multiple industries, buildings are being constructed with integrated Building Automation Systems (BAS) or Building Control Systems

(BCS) that include Building Energy Management Systems (BEMS), access control, fire safety, and other automated systems. 10% of small business owners indicate that energy consumption is the number one largest expense of their business and another 25% indicate that it is in the top two or three expenses.

2.2.2 Real time optimization

The key to real time optimization is providing personnel with mobile access to the data they need, when or even before they need it. On a "smart" factory floor, a manager would be able to walk up to a process and immediately be aware of equipment status, production status, and would be able to make decisions rapidly. The next level would also connect departments, such as supply chain, shipping, and quality who would be mobile-aware of real time production status and able to make speedy, yet informed decisions. Huang et al. proposed a Wireless Manufacturing (WM) framework, carrying out the aforementioned concept by connecting RFID devices installed at workstations, critical tools and components, and containers of work-in-process materials, essentially turning them into "smart" objects. These smart objects are then tracked and any anomalies were reported to the decision makers in real time, enhancing operational efficiency and effective decision making (Huang G. Q., Zhang, Chen, & Newman, 2008). Another affordable application of WM utilizing RFID was designed in a fixed-position operational layout, experiencing similar results, including the reduction of WIP and improved overall process flow (Huang, Zhang, & Jiang, 2007). These proposals were expanded upon in (Zhang, et al., 2015), in which a full architecture was designed to implement these techniques. A real-time information capturing and integration architecture of the internet of manufacturing things (IoMT) was used to integrate the smart objects with the Enterprise Information Systems

(EISs) to help bridge the information gap and allow for the objects to communicate with one another and with decision makers in real time.

From a lean manufacturing standpoint, these techniques have the potential to address several current issues in Just-in-Time (JIT) implementation including the lack of information sharing and communication between stakeholders, insufficient planning systems, lack of timely and precise coordination, demand surges, etc. Xu and Chen propose several IoT solutions to JIT challenges, the first of which being scheduling, which they attribute to a lack of required information sharing, insufficient planning systems, and/or cross-functional conflict (Xu & Chen, 2016). Their proposed solution incorporates real-time resource status monitoring to integrate actual production cycle time, machine status, tooling status, material delivery status, and labor status to create a dynamic schedule. The applications of real time optimization are not limited to a manufacturing environment.

2.2.3 Mass Customization

Another opportunity created by real-time data is the expansion of the Mass-customization production of goods and services. Mass-customization production is the ability to simultaneously optimize the customer satisfaction level and the benefits of mass production for the provider (McCarthy, 2004). One case study demonstrated that RFIDs can be used to better manage the highly stochastic demand of mass-customization production by creating real-time scheduling systems and WIP tracking (Zhong, Dai, Qu, Hu, & Huang, 2013). The use of RFIDs resulted in optimized WIP levels, balanced machine utilization, reduced cycle time, increased product quality, and impressive overall output and profit increases of 18.5% and 47.5%, respectively.

2.2.4 Big Data and business analytics

Forester divides Big Data in four dimensions (4V):

(1) Volume, the amount of data and the technological abilities to manage it;

(2) Variety, the dynamic and unstructured data sources not suited for traditional analysis;

(3) Velocity, the generation speed of new data in near real time; and

(4) Value, the extraction of valuable information from said data (Witkowski, 2016).

Volume, Variety, and Velocity are what distinguish Big Data technologies from traditional data analysis, but the Value dimension brings Big Data to the forefront of this so-called Industry 4.0. The rapidly growing ability to collect enormous amounts of data creates a tremendous need for the proper people and tools to take that data and turn it into something meaningful. As it relates to the Internet of Things, effective analytics models are at the foundation of autonomous decision-making. The data analytics and computer science and engineering research communities are working quickly to address issues such as storage, ownership, and expiry. Some of the most valuable IoT applications involve not only discrete event monitoring, but also gathering and making sense of large amounts of data collected from IoT objects (Ahmed, et al., 2017). Various machine learning and artificial intelligence techniques and algorithms are being used to develop applications that can handle this unprecedented volume of data and achieve automated decision-making (Gubbi, Buyyab, Marusic, & Palaniswami, 2013). Major existing analytics platforms include Apache Hadoop, 1010data, Cloudera data hub, SAP-hana, HP-HAVEn, Hortonworks, Pivotal big data suite, Infobright, and MapR, all of which have strengths and weaknesses depending on their intended use (Ahmed, et al., 2017). The three major types of data analytics include descriptive, predictive, and prescriptive analytics. All three types can extract value from the data produced by IoT devices and technologies. Descriptive analytics define “what has occurred or what is occurring”. Predictive analytics define “what will happen and why”. Finally, prescriptive analytics define “what should I do and why”.

2.2.5 Enhanced Customer Relationship

The Internet of Things provides a unique opportunity for businesses to form direct, real-time relationships with their customers. The most widely recognized example being the new Coca Cola machines, in which the customer selects their drink to specification, and data is sent back for inventory replenishment purposes (Ives, Palese, & Rodriguez, 2016). Considering the versatility of the Internet of Things, however, Automated Inventory Management Systems are not limited to a customer interacting with a Coca-Cola machine or ATM. More complex inventory models are being developed and used to track consumer purchases and create real-time inventory in a retail environment (Khanna & Tomar, 2016; Chandrasekar & Sangeetha, 2014; Li, et al., 2017). Li et al. designed a secure prototype smart shopping system in which all products collected by the customer into his or her cart are tracked using RFID tags on the products, carts and shelving units. Benefits mentioned include reducing queue times for customers, as billing would take place at the cart and improving inventory replenishment by eliminating the need for manual product scanning at both the front and back ends of a purchase.

Similar models are being utilized in the healthcare industry for improved patient care, further proving the wide applications of the Internet of Things. In healthcare, IoT solutions are being considered even for monitoring non-hospitalized patient status and the activation of remote assistance in response to abnormal readings (Amendola, Lodata, Manzari, Occhiuizzi, & Marrocco, 2014) (Pescosolido, et al., 2016).

2.3 Challenges

The bulk of literature on challenges in IoT are addressing the technical challenges being encountered by IoT technology developers. However, these technical challenges are applicable to large and small corporations alike as researchers work to keep up with technological innovations in this field. Implementations challenges, on the other hand, can be more uniquely experienced based on the size of the firm. Therefore, as the focus of this paper is on the small to medium sized businesses' unique experience with IoT, the following section summarizes some of the most common implementation challenges found in IoT literature.

2.3.1 Security

As stated in the previous section, much of this literature on security is technical in nature and goes beyond industry applications to include security challenges for the implementation of IoT in entire cities or countries. Even still, security vulnerabilities are the most referenced challenges companies will face when implementing IoT technologies. These vulnerabilities can lead, at best, to user dissatisfaction (front end bugs), privacy violations (loss of personal data), and monetary loss (ransomware), or, at worst, loss of life, in healthcare and vehicle automation applications (Fernandes, Rahmati, Eykholt, & Prakash, 2017). These outcomes help emphasize how critical IoT security research is and will be for the foreseeable future, as researchers work to secure emerging technologies appropriately. Historically, Operational Technology (OT) groups have relied on physical separation to keep systems secure. By nature, IoT defies this methodology by requiring open connections between previously independent operations. Typically, the security concerns of IoT are broken down into four layers of IoT architecture that go by many names, as it has not yet been standardized. For this research the following terms will be used (other commonly used terms in parenthesis): the application (thing or device) layer, the middleware layer, the network (transport) layer, and the perception layer. The perception layer of the system is made up of the physical sensors that capture data from the environment or other smart objects. The network layer of the system is responsible for connecting to other smart objects as well as for transmitting data. The middleware layer, sometimes omitted, processes the data delivered from the transport layer and supports interoperability. Lastly, the application layer is where services are actually provided to the user. Table 2.1 summarizes some of the major concerns within each layer.

Table 2.1 Security concerns for each layer of IoT architecture

IoT LAYER	VULNERABILITIES
Perception	Malicious node tampering or injection, signal interference
Network	Unauthorized access, spoofing, cloning, network protocol compromise, flooding
Middleware	Context awareness and user privacy, authentication
Application	Data access, authentication, data recovery, software

(Razzaque, Milojevic-Jevric, Palade, & Clarke, 2016; Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015; Jing, Vailakos, & Wan, 2014)

The common threat in each layer are distributed denial of service (DDoS) attacks, which are expressed in different forms in each. In the perception, or physical layer, it may be in the form of signal interference. In the network layer, a DDoS attack might involve overloading, or flooding, a network device with requests, preventing it from processing authentic requests. This section has outlined the current top security issues facing businesses looking to implement IoT technologies. However, it is recognized that as IoT evolves, as will the security concerns. Therefore Chapter 5 will address long term threat mitigation strategies for the small to medium sized business including organizational structure changes, collaboration and risk management.

2.3.2 Data Reliability

Although Big Data is often touted as a revolutionary opportunity to quantify and optimize decision-making, a primary concern that repeatedly comes up in literature is the ability to maintain data integrity as the volume of data grows beyond what most firms have experience managing (Stankovic, 2014). Stankovic emphasizes the importance of minimizing false negatives and false positives in order to prevent a system from being dismissed as unreliable. The problem of data reliability is not only technical in nature and requires a business culture in which employees are accustomed to making data-driven decisions. The following section covers this and other culture challenges for companies' wishing to implement IoT.

2.3.3 Culture

Some of the most commonly mentioned challenges brought upon by the introduction of the Internet of Things into industry all fall under the category of culture change. Three major challenges come up the most often, including marrying the Information Technology (IT) and Operational Technology (OT) groups (Potoczak, 2017; Atos, 2012), abandoning proprietary systems for open standards (Stankovic, 2014; Mainetti, Patrono, & Vilei, 2011), and workforce adaptation (Erol et al. 2016; Glovaa, Sabola, & Vajda, 2014; Gierej, 2017; McAfee & Brynjolfsson, 2012). These three challenges, among others, contribute to the next section which will summarize the challenges involved in business transformation.

IT/OT Merge

Traditionally, OT departments within companies are made up of specialists or engineers, while IT professionals commonly come from a computer science background (Atos, 2012). These differences have commonly contributed to departmental silos. Not only does realignment require the collaboration of employees in each department, but often also requires collaboration between the CIO and COO of the organization, previously corresponding to the IT and OT departments respectively. Potocznak describes the seamless interaction between IT and OT as being an essential piece of the realization of IoT, stating that IoT is only as useful as the data it provides, including the ability for that data to be transformed into real-time actionable analysis (Potoczak, 2017).

Open Standards

Sensors are not new to industry. In fact, temperature sensitivity of electrical resistance in certain materials was detected in the early 1800s and later used by Wilhelm von Siemens in 1860 to develop a temperature sensor using a copper resistor (National Research Councel, 1995). Although sensors have since advanced in capability, sensor networks are still traditionally built on closed or proprietary systems that are virtual islands with limited connection to the rest of the world (Mainetti, Patrono, & Vilei, 2011). In order to realize the potential of the Internet of Things, these islands must be able to communicate openly with one another. For example, open systems would allow data communication across factories, potentially up and down the supply chain (Stankovic, 2014). For companies with expensive legacy proprietary systems, this conversion could seem too large of a barrier to entry.

Workforce Adaptation

In addition to increased transparency, the business models that align with the Internet of Things must be fast and adaptable (Glovaa, Sabola, & Vajda, 2014). Although business models have been shifting this way since the introduction of the Internet, the demand for agility continues to rise along with the complexity of the technology.

McAfee and Brynjolfsson bring to light, in the Harvard Business Review, the impact Big Data could have on traditional brick and mortar businesses. The value of data for the online business has generally always been obvious, and online businesses understood that they compete based on how well they can interpret their customer data. Emphasis is placed on the need for managers to learn to rely less on intuition and experience and lean more on data. The duo summarizes the culture change in the shift from the question “What do we think?” to “What do we know?” (McAfee & Brynjolfsson, 2012) They even go so far as to give examples of management falsifying a data-driven culture, by making decisions and then looking to find the data to back them up. They propose that leaders that can embrace data driven decision making will flourish or be replaced in this new era.

Gierej also places emphasis on customer-orientation for a successful transition to an IoT organization in order to take advantage of the data from IoT, bringing high value to the customer by raising the overall awareness of customers’ needs and wants (Gierej, 2017). The need for flexibility and customer orientation does not end at the management level. As IoT drives decision making lower in the organization, some employees must make the transition from operators to problem solvers (Erol, Jager, Hold, Ott, & Sihn, 2016). In turn, management must be flexible enough to trust and allow the decision making to happen at lower levels in their organization.

The necessity of an adaptable and customer-focused business model presents the possibility of advantage for the SMB that must be leveraged in a successful implementation of the Internet of Things. Section 2.4 will go into more depth on the dynamic nature, flexible management styles, and customer-orientation of the SMB.

2.3.4 Business Model Transformation

There are two ways to view the impact of the Internet of Things on current and future business models. One is that the Internet of Things is opening the door to allow for the creation of more effective and innovative business models. The other way is to consider the fact that the Internet of Things might actually be rendering current business models obsolete, forcing businesses to adapt and find new models. Ehret and Wirtz discuss both the opportunities the Internet of Things will present as well as the challenges that will threaten existing business models (Ehert & Wirtz, 2017). They emphasize that manufacturing must implement more service-based models in order to deal with the uncertainty of the developing IoT landscape. In this kind of model, they propose the providers and clients must share and accept both the benefits and risks of utilizing IoT in their business transactions.

Fleisch, Weinberger, and Wortmann summarize how the Internet of Things will shape business models in the same way the Internet and Information Technology has shaped many successful business models in the last few decades, citing many examples including E-Commerce, Freemium, and Performance-based Contracting (Fleisch, Weinberger, & Wortmann, 2015)

2.4 The Unique Position of the Small and Medium Sized Business

In this work's search through the literature, very little, if any, literature was found that specifically tailored to IoT applications within a small or medium sized business. Therefore, in order to formulate a relevant phased IoT implementation framework for small and medium sized businesses, it was necessary to compile and understand the distinct position of these businesses, including the unique strengths and weaknesses, opportunities and threats due to their size. The method chosen for this compilation was a SWOT analysis. SWOT is an acronym for strengths, weaknesses, opportunities and threats. SWOT analysis is a qualitative structure analysis of the aforementioned characteristics and can be applied to an organization, an industry, a business venture or simply a project. The SWOT analysis in this case intends to generalize these elements for the SMB such that they can be evaluated for relevance in IoT implementation in later chapters.

2.4.1 Strengths and Opportunities

Many of the strengths and opportunities of the SMB, summarized in Figure 2.1, are studied under the broader cultural characteristic, entrepreneurship. Smaller organizations often have maintained the entrepreneurial spirit of the leaders who started the business, due to the smaller distance between the lowest level of the company and the owners and executives.

Smaller organizations commonly have a less formal organization structure, which inherently promotes flexible business processes. The internal communication networks are often informal, but efficient, able to reorganize quickly in response to changes in the external environment (Rothwell & Dodgson, 1991). Additionally, employees of smaller organizations are more likely to remain loyal, as the organization is more able to provide individual attention and empowerment (Harrigan & Miles, 2014). Smaller organizations also tend to form closer bonds with their customers, often developing an intuitive knowledge of their customers' needs and potential market trends with the result of high levels of personalization and a customer satisfaction and retention focus (O'Dwyer, Gilmore, & Carson, 2009). A key term to understand when summarizing the competitive advantage of the SMB is market orientation (MO), commonly defined as a business philosophy with the focus of understanding customers' needs and meeting them. Narver and Slater defined the three components of MO: customer orientation, competitor orientation, and interfunctional coordination (Narver & Slater, 1990). All three of

STRENGTHS	Dynamic and Flexible	(Safiullin, Shaidullin, Ulesov, & Shigabieva, 2014) (Odlin & Benson-Rea, 2017); (Fiegenbaum & Karnani, 1991)
	Innovative	(O'Dwyer, Gilmore, & Carson, 2009)
	Employee loyalty	(Harrigan & Miles, 2014); (Rogers, 2004)
	Customer Orientation	(Krajnakova, Navikaite, & Navickas, 2015); (Harrigan & Miles, 2014);(Coviello, Brodie, & Munro, 2000); (Odlin & Benson-Rea, 2017); (Brockman, Jones, & Becherer, 2012)
WEAKNESSES	Higher Cost of Regulation	(Calcagno & Sobel, 2014); (Rothwell & Dodgson, 1991)
	Qualified technical manpower	(Rothwell & Dodgson, 1991); (Nooteboom, 1994); (Krishnan & Scullion, 2017); (Carroll, Marchington, & Earnshaw, 1999)
	Instability	(Miller & Toulouse, 1986).
	Capital resources	(Rothwell & Dodgson, 1991); (Vossen, 1998)
	Economies of Scale	(Nooteboom, 1994); (Rothwell & Dodgson, 1991);
OPPORTUNITIES	Technological Innovation	(Singh, Khamba, & Tarun, 2017); (Nooteboom, 1994)
	Interfunctional Coordination	(Rothwell & Dodgson, 1991)
	Market Orientation	Alpkan, Yilmaz, & Kaya (2007); (Narver & Slater, 1990) (Raju, Lonial, & Crum, 2011)
	Community Involvement	(Young & Cater III, 2016); (Zatepilina-Monacell, 2015)
	Effective Change Management	(Fiegenbaum & Karnani, 1991); (Ko & Liu, 2017)
THREATS	Overexpansion and Resource Shortages	(Gaskill, Van Auken, & Manning, 1993)(Cassell, Nadin, Gray, & Clegg, 2002)
	Managerial and Planning Failures	(Gaskill, Van Auken, & Manning, 1993)
	Competitive Environment	(Gaskill, Van Auken, & Manning, 1993)
	Poor capital management	(Gaskill, Van Auken, & Manning, 1993)

Figure 2.1: A Generalized SWOT Analysis for the Small to Midsize Business

these characteristics are positively associated with performance for smaller organizations in literature (Brockman, Jones, & Becherer, 2012; Raju, Lonial, & Crum, 2011). The SMB is said to possibly have an advantage over larger corporations, as their closer contact with customers, agility, adaptability and innovativeness can all contribute to higher levels of market orientation and the three preceding requirements (Pelham, 1999; Raju, Lonial, & Crum, 2011).

2.4.2 Weaknesses and Threats

Often, the advantage of larger firms are attributed to resources, while the advantage of smaller firms are argued in terms of behavioral characteristics, including those discussed in the previous section (Vossen, 1998). The weakness of the small business is therefore summarized by their ability to obtain the capital and employees necessary to scale their business. "Economies of Scale" is often the first and most commonly mentioned weakness or disadvantage of a smaller firm (Rothwell & Dodgson, 1991).

The ability for a small business to find, onboard, and maintain qualified employees that together have all of the skills necessary to make the business successful is a complex challenge that can be broken down into multiple weaknesses and threats. A small business may not have the reputation to attract the most talented employees, or the human resources organization's help in motivating those employees to join the company (Carroll, Marchington, & Earnshaw, 1999). Even once the right employees are identified, a smaller organization tends to have less capital to absorb the onboarding costs, which could be even higher when trying to recruit the best talent. While a smaller organization struggles to acquire the necessarily employees to support the growth of their business, a threat emerges as organizational gaps increase the risk of process breakdowns that could harm the business.

Gaskill et al. performed a factor analytic study of the perceived causes of small business failure, in which they identified four leading factors, or as called in this review, threats, that are attributed to business failure (Gaskill, Van Auken, & Manning, 1993). The factors include managerial and planning failures, poor capital planning, the competitive environment, and grown and overexpansion. Furthermore, Miller and Toulouse remarked on the influence of a CEO's personality on strategy and structure for smaller firms (Miller & Toulouse, 1986). Although this influence can be positive, it can also lead to instability, as the firm can more easily be swayed by one person or a small number of persons' behavior.

Chapter 3: A Survey on IoT Awareness and Use in the SMB

3.1 Purpose

A survey was conducted of owners, executives and employees of SMBs in order to gain a better understanding of the current awareness and use of "Internet of Things" technologies. The intention of the work is to contribute to the answers to the following research questions:

1) Is IoT relevant and useful for the small to medium sized business? How is it useful?
2) How do small to medium sized businesses perceive IoT?

   Additional Contributing Analysis:

   - Does a relationship exist between the role of the respondent and his or her perception of IoT?
   - Does a relationship exist between the industry of the firm and the firm's perception of IoT?

3) What are the perceived barriers to entry?
4) Is awareness a barrier to the adoption of IoT technologies in SMBs?

This information will be used to help answer the remaining research questions outlined in the Introduction as well as assist in the creation of a viable and competitive business plan for the implementation of IoT.

3.2 Design

3.2.1 Target Population

The target population for this study included owners, executives, VPs, and other senior level managers of small to medium-sized firms. In addition, managers with responsibilities surrounding logistics, supply chain, warehousing, and other related areas were also included, as it was believed these respondents would be able to speak to how IoT is being implemented in their company as well, if not better, than higher level management. The definition of a small to medium size firm was less than 1000 employees across all locations.

3.2.2 Sample Size

Owners and executives of small to medium sized businesses amount to a large population size, given that, according to the U.S. Small Business Administration, over 99.5%, or over 5 million, of all US businesses are categorized as small to medium sized (having less than 1000 employees). The number of respondents needed to represent this population size at a 95% confidence level with 2% margin of error would be 2400, and with a 5% error would be 385. Therefore this survey was conducted with the knowledge that a highly statistically significant sample size would be challenging to achieve without a larger platform and potentially survey incentives. However, even lacking a high level of statistical significance, the answers provided in combination with the literature can still provide value in formulating the direction of further research.

3.2.3 Survey Questions

This survey incorporated structured, or fixed response, survey questions in order to enable analysis as well as reduce overall survey time to decrease the nonresponse rate. However, in order to simultaneously evaluate the completeness of the choices, an option was given, where appropriate, for the respondent to input an answer that was not included in the choices. In addition, rating questions were utilized to evaluate the respondents' opinion, knowledge, or use. One open-ended question was incorporated into the end of the survey in order to give the respondent the opportunity to fill any gaps of the information they were willing to share, but was not requested. No personal information was gathered and respondents were asked to answer a question indicating consent to participate at the beginning of the survey.

The survey was designed such that it might also function as an educational tool for SMB owners, executives, and employees. Toward the beginning of the survey, a question was included that requested the respondent's overall general impression upon hearing the term the "Internet of Things". Answer choices include: "Definitely will provide value", "Might provide value", "Will not provide value", "Likely a distraction from our core business", and "I'm not sure what it is" (CompTIA, 2016). After this question, the respondent is queried about their companies' awareness and use of common IoT technologies followed by IoT applications. At this point, the survey again requests the respondent's overall general impression upon hearing the term the "Internet of Things". This survey strategy is an attempt at measuring whether being made aware of the benefits and uses of IoT might help change the mind of someone who otherwise did not understand its value.

The survey goes on to inquire about the use and knowledge of IoT technologies, followed by IoT applications that were some of the most commonly mentioned in literature. Respondents are then asked what they believe are the greatest barriers of implementing IoT in their organization, as well as the greatest benefits of successful implementation. The respondents are asked how much work is done in their company on mobile devices in an attempt to gauge the technological engagement of their organization. Finally, the respondents are asked about what cybersecurity solutions are implemented at their company and whether their company has experienced a cyberattack. The full set of survey questions can be found in the Appendix.

3.3 Survey Limitations

3.3.1 Nonresponse Bias

One of the concerns in collecting data for a survey with the intention of measuring awareness of a topic is nonresponse bias. Nonresponse bias describes the phenomenon where the expected values deviate due to meaningful differences between respondents and non-respondents. In this case, it could be possible that contacted individuals are more likely to respond to the survey if that individual already has exposure or an opinion on the Internet of Things. This could bring individuals on either extreme in opinion, potentially favoring those with extremely positive opinions. One method to help mitigate the risk of nonresponse bias would be to present surveys of an unknown topic to highly incentivized participants. This could potentially be more effective in capturing awareness rates. In addition, if the research could be performed on pre-screened individuals, analysis could be performed on what type of individuals are more or less inclined to respond.

3.3.2 Individual and Industry Variation

Section 4.3.1 summarizes an analysis of the impact of a respondent's role and industry on the perception of IoT. A significant difference between role or industry and IoT perception might indicate differences in the rest of the survey. One assumption of this survey is that owners, executives, and other individuals from the same organization would answer these questions almost if not completely identically. However, this might not be the case. Individual opinion will be present in the results. Therefore, the results must be interpreted with the knowledge that they reflect the opinion of the individual that was surveyed, and not the opinion of the entire company at which that individual is employed. In order to achieve more accurate representation of SMBs, a much larger study must be performed, incorporating not only a larger number of organizations from more evenly distributed industry populations, but also incorporating many different people at different levels in those organizations.

Chapter 4: Results

4.1 Rates and Demographics

4.1.1 Response Rates

The researcher reached out to 243 SMB owners, executives, and others on LinkedIn by requesting to connect with them in order to collaborate on this research. The message included the survey link and a brief description of the research's purpose. Of the 243 connection requests, 165 individuals, or 67.9%, accepted the connection. Of those individuals, several responded with interest in taking the survey and receiving the published work. 72 individuals began the survey and out of those, 53 individuals completed the survey. Four survey responses were disqualified due to a firm size of over 1000 employees.

4.1.2 Response Demographics

The following three figures illustrate the demographics of the survey respondents. Figure 4.1 summarizes the role of the respondents. Figure 4.2 summarizes the size of the organization of the respondents and Figure 4.3 summarizes the industries in which these organizations operate. 39% of the respondents were owners of organizations with fewer than 100 people while only 2% were owners of larger organizations. 40% of the respondents belonged to companies in the manufacturing industry, although approximately half of the "other" industries were also in manufacturing. The second largest industry category was "Other", and specific responses included consumer goods, wholesale/retail distribution, distillery, biotechnology, recruiting, cabinetry, construction, and management consulting. Some of these options were included on the survey. It is noteworthy that 78% of the represented organizations would be classified as small rather than medium-sized businesses.

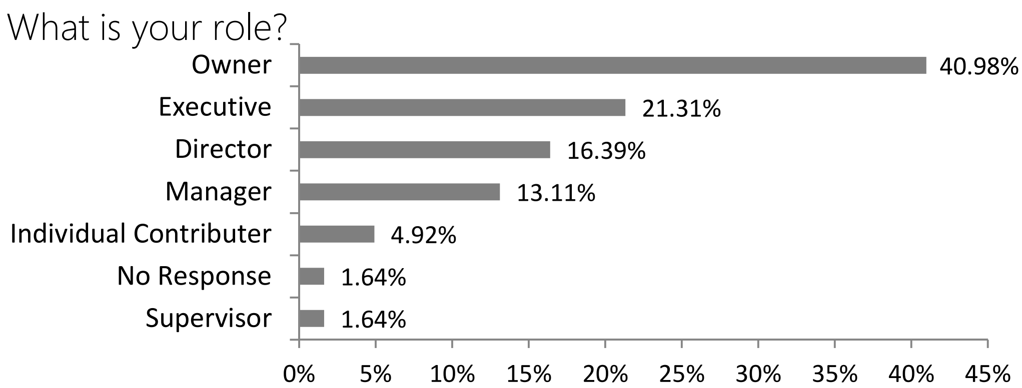

Figure 4.1 Role of Respondents

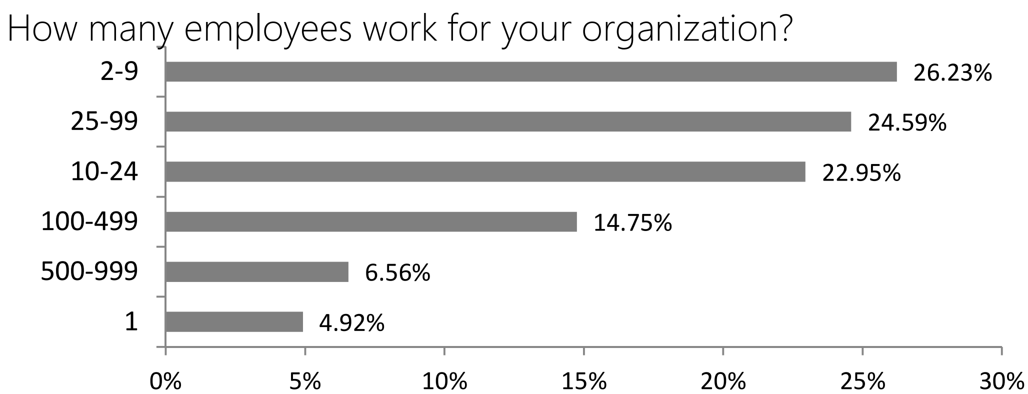

Figure 4.2 Number of Employees in Organization

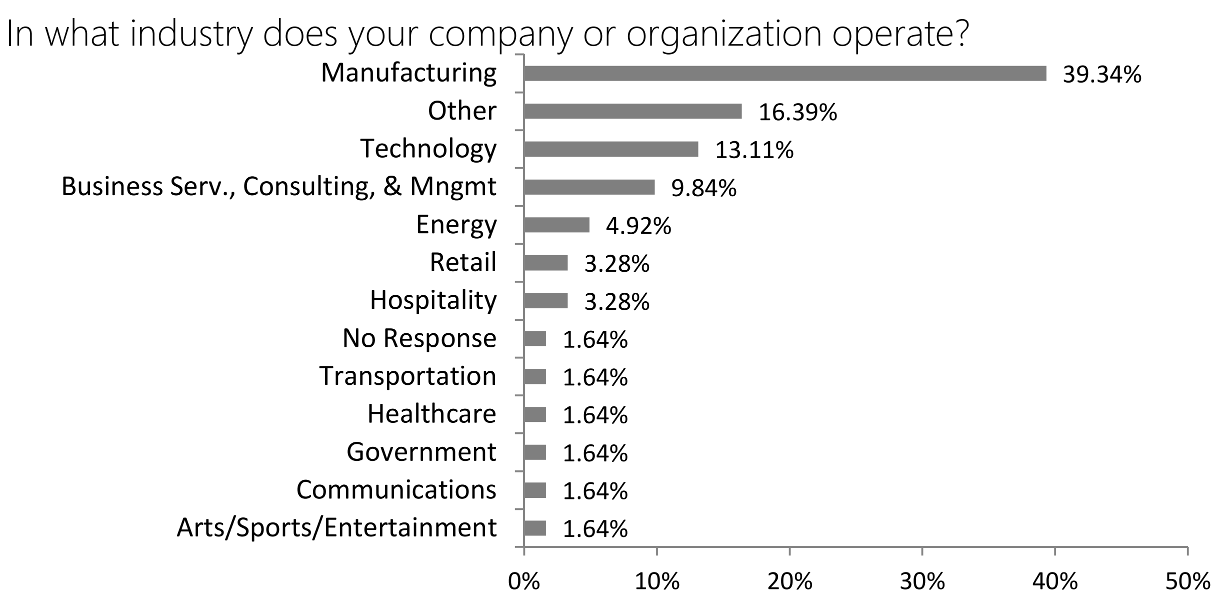

Figure 4.3 Industry Breakdown

4.2 Is IoT relevant and useful for the small to medium sized business? How is it useful?

Respondents were given a list of IoT technologies and applications, and asked whether not they were making use of them, interested in using them, not interested, or if the application or technology was not applicable to their company. 83.6% of respondents listed at least one IoT technology that was being used in their organization, and nearly 91% indicated interest or use in at least one technology. 65.4% of respondents listed at least one IOT application that was being used in their organization, and 80.7% indicated that would like to use at least one application. Nearly 91% indicated interest or existing use of at least one application.

The top IoT applications being used by the respondents were smart lighting, waste management solutions, intrusion detection systems, and temperature monitoring systems. Other than the top applications being used, the top applications that respondents were interested in were smart product management, energy use, shipment monitoring, and remote control of appliances. The applications that respondents were the least interested in, or found inapplicable, were structural health, radiation level detection and storage incompatibility detection. Structural health may be included in this list because smaller organizations are less likely to own their buildings. The latter two are more specific applications, and therefore the low interest in an expected result. The most popular IoT applications according to this survey are in line with what was found in the literature search.

The top IoT technologies being used by the respondents were cloud computing, Wi-Fi direct, low energy wireless, and low energy Bluetooth. Other than these, the top technologies that the respondents indicated they would like to use are RFID, wireless sensor networks (WSN), and wearables. The technologies that respondents were the least interested in, or found inapplicable, were radio protocols (e.g. ZigBee) and LTE-A. The survey did not ask why the respondents answered this way, but one theory would be that these technologies are less known and less talked about on professional social media platforms. Figures B.1 and B.2 in the Appendix are color coded summary tables of the response to the IoT technology and applications questions, respectively.

In addition to inquiring about the most used and most intriguing IoT technologies and applications, respondents were asked what they believed would be the top benefit of implementing IoT in their organization. Figure 4.4 summarizes the responses. 27.8% of respondents indicated cost savings from operational efficiencies would be the greatest benefit. A little over 20% indicated that they saw the new and better streams of data to be of greatest benefit. The third most beneficial aspect mentioned was new and better customer experiences, with 16.7% of responses.

Figure 4.4: IoT Benefits (CompTIA, 2016)

Respondents were also asked about their current and future plans to implement IoT into their organization. Although over 65% of respondents indicated their company was using one of the IoT applications above, only 13% of respondents indicate their company has an IoT initiative underway. Figure 4.5 summarizes the responses.

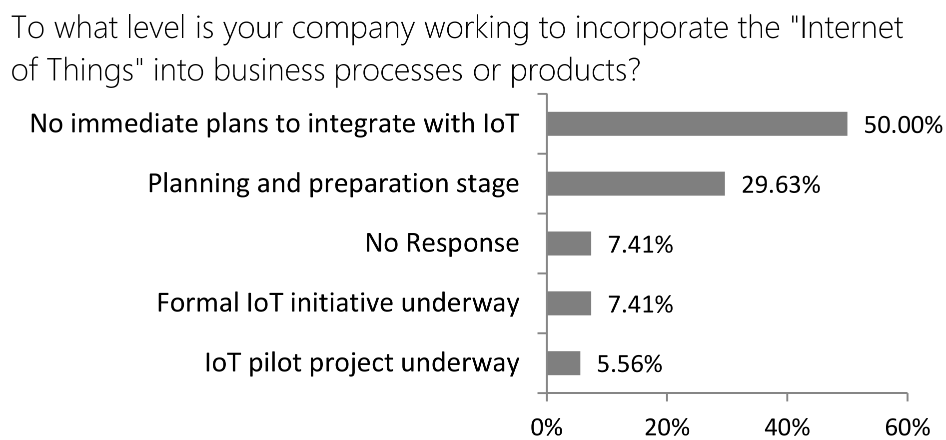

Figure 4.5: IoT project status (CompTIA, 2016)

Potentially, respondents did not see their use of IoT applications in isolated environments as significant as an "IoT pilot" or "IoT initiative", as this question implies. In the future, less general terms and more specific examples could potentially help eliminate such discrepancies.

These results preliminarily indicate that IoT is indeed useful to the SMB, with the majority of respondents indicating that they were already using or interested in IoT technologies and applications and the majority also identifying specific benefits. The top IOT applications and technologies, listed previously, that are being used or that SMBs are interested in provide some insight into how IoT is useful for them. Finally, according to the respondents, they believe the greatest benefits of IoT would be cost efficiencies, better streams of data, and better customer experiences.

4.3 How do small to medium sized businesses perceive IoT?

At the beginning of the survey, respondents were asked the following question, “What is your overall impression when you hear the term ‘Internet of Things’ in the context of your organization?” Figure 4.6 shows the results of all participants, including those that may not have completed the rest of the survey.

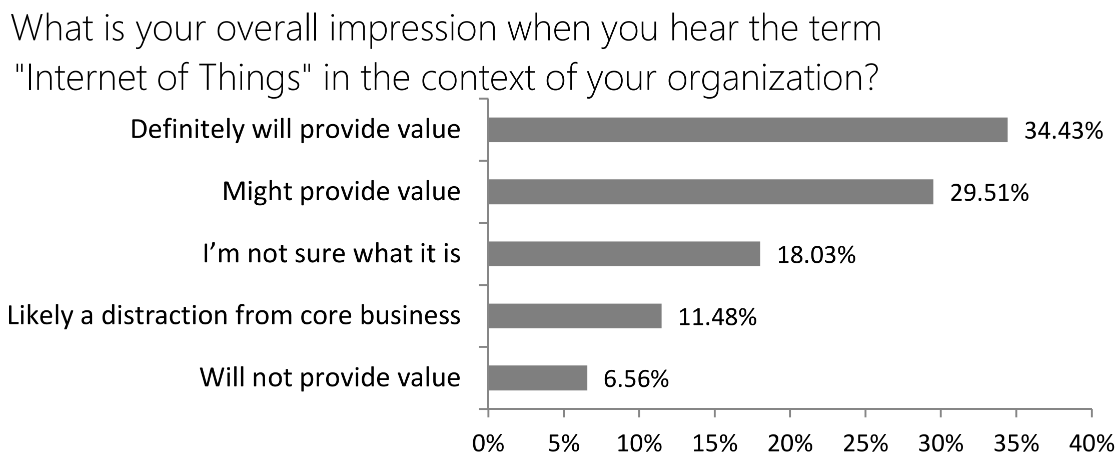

Figure 4.6: IoT Perception before survey (Includes Incomplete Responses)

34% of respondents indicated that they believed IoT would definitely provide value. Another nearly 30% indicated that they thought it might have value. 18% admitted to not knowing what IoT was, and 18% responded with a negative impression of IoT. These results indicate that SMBs have a fairly positive perception of IoT. Sections 4.3.1 and 4.3.2 dive further into these results to better understand these impressions.

4.3.1 Does a relationship exist between the role of the respondent and his or her perception of IoT?

To analyze the relationship between the role of the respondent, an independent categorical variable with more than 2 levels, and IoT perception, a dependent ordinal categorical variable with more than 2 levels, a cross tabulation and chi-square analysis was selected. The null hypothesis, H_o, is that there does not exist a relationship between the role of the respondent and his or her perception of IoT. In order to reach the minimum assumptions required for a chi-square analysis, the roles were grouped into Director level and above, and the Manager level and below. In addition, the levels of IoT perception were grouped into positive, neutral and negative opinions. "Definitely will provide value" and "Might provide value" were labeled as positive. "I'm not sure what it is" was labeled as neutral. "Will not provide value" and "Likely a distraction from our core business" were labeled as negative. The groupings are shown in Table 4.1 as well as the results of the first step of the analysis, calculating the row and column totals.

Table 4.1: Role/Perception of IoT: Observed Values

	Owner/ Executive/ Director	Manager/ Supervisor/ Individual Contributor	Row Totals
Positive	34	4	38
Neutral	8	3	11
Negative	6	5	11
Column Totals	48	12	60

Next, the expected frequency of each cell was calculated using the following formula:

$$E_{ij} = \frac{T_i \times T_j}{N}$$

Where

E_{ij} is the expected frequency for the cell located in the *i*th row and the *j*th column

T_i is the total number of observations in the *i*th row

T_j is the total number of observations in the *j*th column

N is the total number of observations in the study

In order to meet the minimum assumptions for a chi-square test, each cell value must have an expected frequency greater than 1. In addition, at least 80% of the expected values should be greater than 5. The calculation of this contingency table met the first requirement, however, only 67% of the expected values were greater than 5. Table 4.2 summarizes the calculated expected values.

Table 4.2: Role/IoT Perception: Expected Values

	Owner/ Executive/ Director	Manager/ Supervisor/ Individual Contributor
Positive	30.4	7.6
Neutral	8.8	2.2
Negative	8.8	2.2

Using the observed and expected values, the chi-square value for each cell is calculated and summated using the following formula:

$$\chi^2 = \sum \frac{(E_{ij} - O_{ij})^2}{E_{ij}}$$

Where

E_{ij} is the expected frequency for the cell located in the ith row and the jth column

O_{ij} is the observed frequency for the cell located in the ith row and the jth column

A chi-square of χ^2=6.94 was calculated for the contingency table. Table 4.3 summarizes the chi-square values for each cell. The degrees of freedom for chi-squared were calculated using $df = (i - 1)(j - 1)$ where *I* is the number of rows and *j* is the number of columns. Given $i = 3$ and $j = 2$, *df* is 2.

Table 4.3 Role/IoT Perception: Chi Square Values

	Owner/ Executive/ Director	Manager/ Supervisor/ Individual Contributor
Positive	0.426315789	1.705263158
Neutral	0.072727273	0.290909091
Negative	0.890909091	3.563636364

The conventional significance level, or alpha, of .05 is then used to determine a critical value of 5.99. With 2 degrees of freedom, and an alpha of .05, the calculated value of 6.94 is greater than the critical value of 5.99. Therefore, the null hypothesis, H_o, that there does not exist a relationship between the two variables can be rejected. Given the lower than suggested expected values for the chi-square test, this result was confirmed using the Freeman-Halton extension of the Fisher exact test, which provided an exact p-value of 0.022. This p-value being less than .05 provides confirmation of the significant results of the chi-square test.

This result requires further investigation in order to identify a cause, however one potential cause for a significant difference in opinion is simply the knowledge level or strategic insight of employees at different levels of a smaller organization. The two types of errors that can be made during this test are called Type I and Type II errors. A Type I error is failing to accept the null hypothesis when it is true while a Type II error is accepting the null hypothesis when it is false. Limitations of the Chi-Square test and the Freeman-Halton extension of the Fisher exact test are the ability to describe the nature or strength of the relationship, or to take into account the ordinal nature of the perception variable ranging from most negative to most positive. In order to avoid making errors, these calculation were performed using groupings. However, a larger study would allow for more granularity in the analysis.

4.3.2 Does a relationship exist between the industry of the firm and the firm's impression of IoT? To help create a more complete answer to the question, how does the SMB perceive IoT, the relationship between the industry and the impression of the respondent is analyzed for variation significance. In order to meet the minimum requirements for a Chi-Square test, the industries were grouped into manufacturing and non-manufacturing and the IoT perception was grouped into positive, neutral, and negative in the same manner as outlined in the previous section. This will limit the extent of the analysis to the comparison of these two industry groups, however, this analysis will be more accurate. A larger sample size must be taken in order to evaluate a larger group of industry types.

The same analysis as was performed in the previous section was repeated and the results are displayed in tables 4.4, 4.5 and 4.6. The null hypothesis was that there does not exist a relationship between the perception of IoT and the industry of the respondent. In order to meet the minimum assumptions for a chi-square test, each cell value must have an expected frequency greater than 1 and at least 80% of the expected values must be greater than 5. The expected

Table 4.4: Industry/IoT Perception: Observed Values

	Manufacturing	Non-Manufacturing	Row totals
Positive	23	16	39
Neutral	4	6	10
Negative	5	6	11
Column totals	32	28	60

Table 4.5: Industry/IoT Perception: Expected Values

	Manufacturing	Non-Manufacturing
Positive	20.8	18.2
Neutral	5.333333333	4.666666667
Negative	5.866666667	5.133333333

Table 4.6: Industry/IoT Perception: Chi-Square Values

	Manufacturing	Non-Manufacturing
Positive	0.232692308	0.265934066
Neutral	0.333333333	0.380952381
Negative	0.128030303	0.146320346

values for this contingency table met the assumptions required for the chi-square test. 83% of the expected values were greater than 5 and all of the expected values were greater than 1.

A chi-square value of χ^2=1.487 was calculated for the contingency table. The degrees of freedom for chi-squared were calculated using $df = (i - 1)(j - 1)$ where i is the number of rows and j is the number of columns. Given $i = 3$ and $j = 2$, df is 2. The conventional significance level, or alpha, of .05 is then used to determine a critical value of 5.99. With 2 degrees of freedom, and an alpha of .05, the calculated value of 1.487 is smaller than the critical value of 5.99. Therefore, the null hypothesis, H_o, that there does not exist a relationship between the perception of IoT and the industry of the respondent cannot be rejected.

Although the Chi-Square test could not demonstrate that the likelihood of these differences being due to random variation less than 5%, a larger sample may be able to provide more insight into the relationship between industry and IoT perception, as further industry categories could be evaluated and compared. In addition, multiple employees from the same company could provide responses in order to better represent the participating companies.

4.4 What are the perceived barriers to entry?

Respondents were asked what they believed to be the top three barriers to implementing IoT in their organizations. 142 total responses were given from the 54 respondents who answered the question. The top barriers indicated were return on investment (46.3%), lack of internal IT expertise (37%), integrating IoT solutions with current systems (29.6%), and security risks (25.9%), where the number in the parenthesis indicates the percentage that barrier was indicated out of the total responses. A summary of the responses given can be found in Figure 4.7.

What do you believe are the top three biggest barriers to implementing IoT in your organization or company?

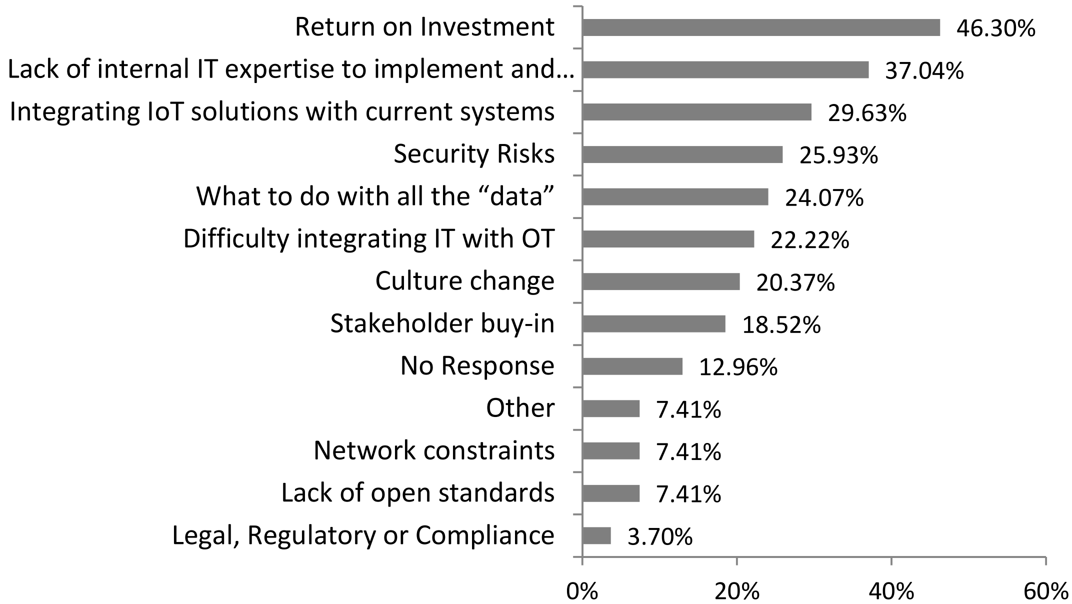

Figure 4.7: IoT Barriers to Entry

4.5 Is awareness a barrier to the adoption of IoT technologies in SMBs?

In order to determine whether awareness might be a barrier for IoT adoption, the pre- and post-survey results for IoT perception were analyzed to see if respondents had a change in opinion once they had been educated on the benefits and applications of IoT. 53 respondents answered both questions. Of the 53, 71.7% made no change in their opinion. 22.6% changed their opinion positively, and 5.6% changed it negatively. Of the 38 respondents that had no change in their answer, 18 had already selected the most positive answer, “Definitely provides value”. Figure 4.8 contains a summary of responses.

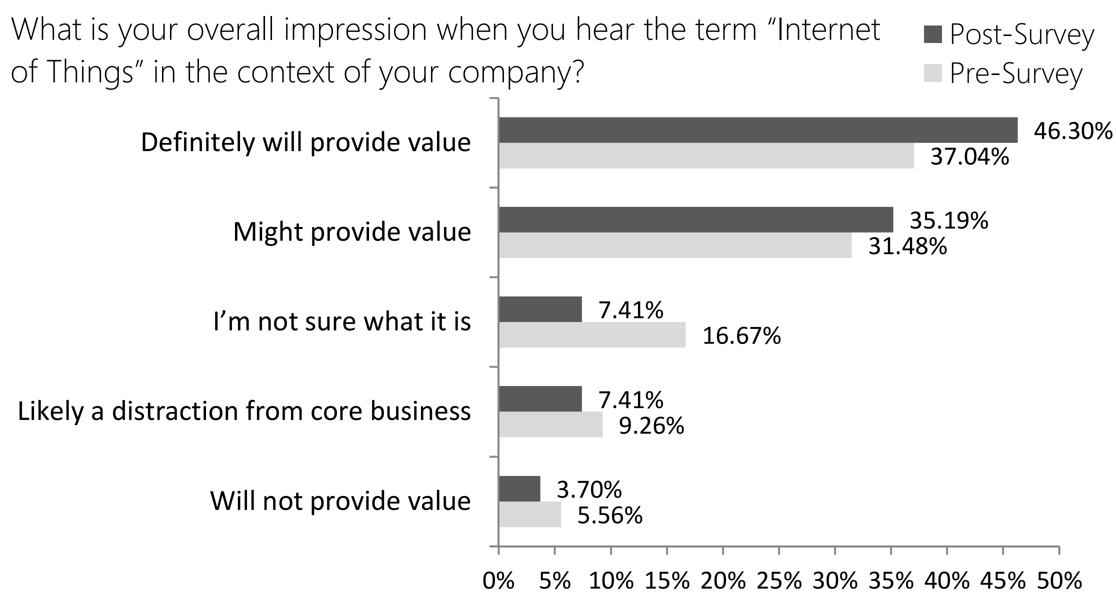

Figure 4.8: IoT Perception before and after survey (Completed Surveys only)

In order to measure whether taking the survey had any impact on the respondent’s impression of IoT, a McNemar test for bias or directional change was performed (Bishop, Fienberg, & Holland, 1975). The McNemar test is traditionally performed on a 2x2 matrix of nominal data. Therefore the McNemar test for directional change was performed to be able to account for the five ordinal categories of IoT perception. This test compares the total frequency of responses above the main diagonal of the matrix with the total frequency of responses below the main diagonal. A significant result in this case implies that there was an overall improvement or worsening of responses between the first and second condition, pre- and post-survey. Table 4.7 summarizes the contingency table along with the row and column totals. Tables 4.8 and 4.9 show the data transformed into a four dimensional array, with a new variable, k, to indicate pre- or post-survey improved results. The sum of frequencies above and below the main diagonal will then be used in McNemar's test statistic, shown below, to calculate the Chi-Square value.

$$X^2 = \frac{(b-c)^2}{b+c}$$

$$where\ b = \sum_{i>j} x_{ij}\ and\ c = \sum_{i<j} x_{ij}$$

The number of cases where the Pre-Survey level was higher was 2, and the number of cases where the Post-Survey level was higher was 12. The chi-square value calculated was 7.143, the degrees of freedom were 1 and the p-value was 0.0075. At 95% significance, the p-value of $0.0075 < 0.05$, therefore the difference in directional change is significant. This result helps to address the original question, is awareness a barrier to IoT implementation, in demonstrating that the impressions of the respondents of the survey were able to be swayed once they were given examples of how IoT could be of benefit to them through lists of technologies and applications. One interpretation of this result is that the negative or neutral impressions of IoT were due to misunderstandings of its benefits, rather than an actual negative or neutral perception. Therefore, unawareness of IoT could be preventing SMBs from pursuing its implementation.

Table 4.7: Pre- and Post- Survey summary table

Pre-Survey	Post-Survey: Likely a distraction	Will not provide value	I'm not sure what it is	Might provide value	Definitely will provide value	Col Totals
Likely a distraction	3	0	1	1	0	5
Will not provide value	0	2	0	1	0	3
I'm not sure what it is	1	0	3	3	2	9
Might provide value	0	0	0	12	4	16
Definitely will provide value	0	0	0	1	19	20
Row Totals	4	2	4	18	25	53

Table 4.8: Pre-Survey Better k = 1

	(1)	(2)	(3)	(4)	Totals
(2)	0	-	-	-	0
(3)	1	0	-	-	1
(4)	0	0	0	-	0
(5)	0	0	0	1	1
Row Totals	1	0	0	1	2

Table 4.9 Post-Survey Better k = 2

	(1)	(2)	(3)	(4)	Totals
(2)	0	-	-	-	0
(3)	1	0	-	-	1
(4)	1	1	3	-	5
(5)	0	0	2	4	6
Row Totals	2	1	5	4	12

Chapter 5: Recommendations: A Maturity Model

5.1 Overview of the Model

A gap was identified during the literature search of IoT implementation in small to medium sized businesses. The few pieces of literature that did cater to small to medium sized businesses did not propose how a business might begin to introduce IoT technologies into their organization. This chapter makes a theoretical contribution by combining the literature on the strengths and weaknesses of the small to medium sized business with the results of the survey as well as the literature examining the challenges and potential countermeasures, and the opportunities and applications of IoT into a series of recommendations for implementation. These recommendations are given in the form of a "Maturity Model" that will cover the steps from infancy to a fully mature implementation of IoT solutions.

These steps are broken down into four phases that are primarily identified by the "reach" of the IoT applications during that phase. Phase 1 begins with a pilot test. Phase 2 increases the scope to internal processes. Phase 3 introduces IoT to the supply chain and other external processes, and finally Phase 4 initiates customer engagement. This chapter will begin by discussing of IoT connectivity levels and at what point during the four phases each level of connectivity should be reached. Then, the challenges included in the Literature Review will be addressed on an individual basis, incorporating the strengths and weaknesses of the SMB into the discussion. Finally, the four phases will be described in more detail, including, when possible, real world examples or case studies to help illustrate the strategies and/or intended outcomes of that phase.

5.2 IoT Connectivity Categories

One of the key drivers behind a businesses' ability to progress to the next phase of IoT implementation is the progression of the IoT connectivity. Several articles and books model similar progressions of IoT connectivity and navigating through the steps can and will look different for different organizations. Porter and Heppelmann outline four capability levels that "smart" IoT products fall into in the following diagram. (Porter & Heppelmann, 2014) Each category builds on the previous, in that control requires monitoring, optimization requires monitoring and control, and so forth.

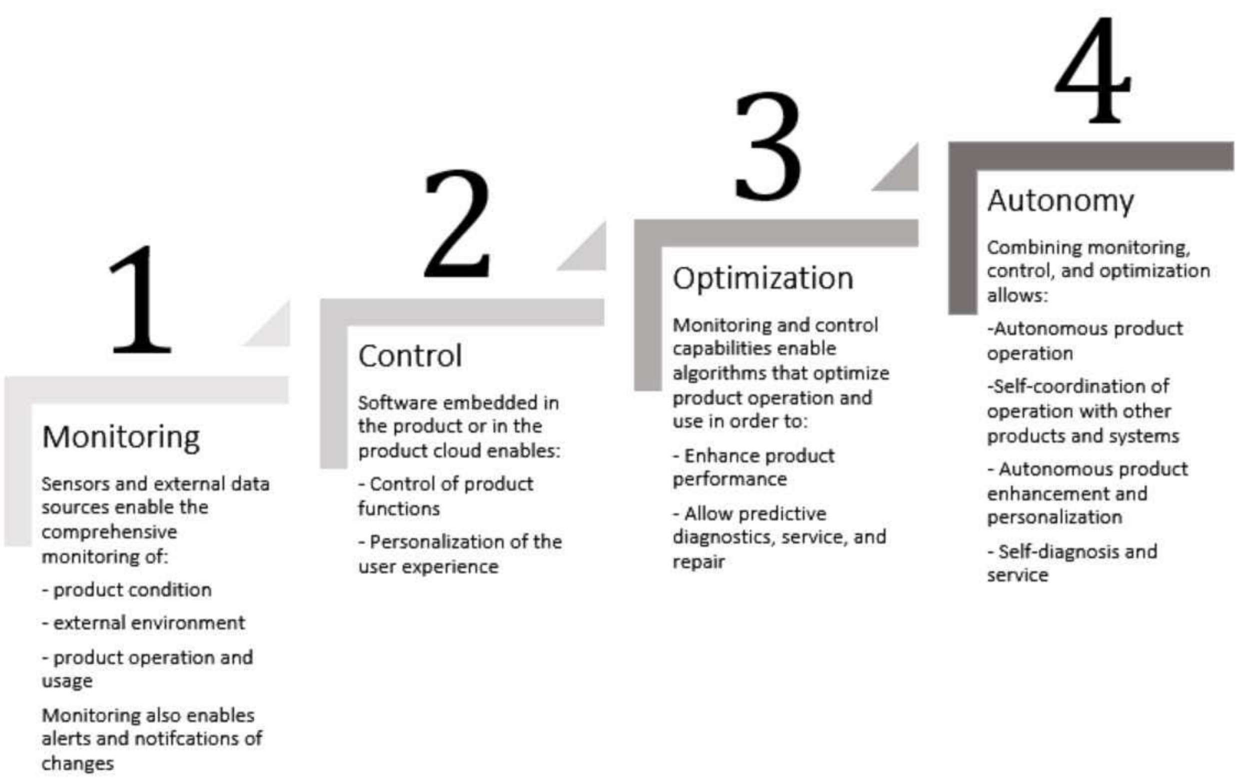

Figure 5.1: Capabilities of Smart, Connected Products (Porter & Heppelmann, 2014)

The first level includes connecting devices in a standalone system using open protocols, introducing a simple but comprehensive monitoring system. The second involves the bridging of the standalone systems into a larger plant-, facility-, or organization-wide network to increase visibility. The third incorporates a platform that enables optimization and data collaboration and the fourth involves data-induced autonomous decision making across different areas of the business or across multiple plants and facilities, if they exist. The IoT implementation should progress through levels 1, 2, and 3 amongst internal business processes in Phase 1 and 2 before entering Phase 3 and introducing external suppliers, and the fourth level should proceed Phase 4, or engagement with the customer. Figure 5.2 provides an outline for the four phases.

<table>
<tr><th></th><th>REACH</th><th>APPROACH</th><th>CONNECTIVITY</th></tr>
<tr><td>PHASE 1</td><td>Isolated Testing/Pilot</td><td>• ROI Confirmation
• Implement several “IoT in a box” solutions
• Staffing: Identify gaps</td><td rowspan="4">MONITORING
CONTROL
OPTIMIZATION
AUTONOMY</td></tr>
<tr><td>PHASE 2</td><td>Internal Processes</td><td>• Expand into other internal processes
• Analytics software
• Staffing: Engage a consultant</td></tr>
<tr><td>PHASE 3</td><td>External Processes</td><td>• Incorporate supply chain
• Staffing: Reach internal Supply Chain competency</td></tr>
<tr><td>PHASE 4</td><td>Customer</td><td>• Engage the customer
• Innovate
• Staffing: Reach internal IT Competency</td></tr>
</table>

Figure 5.2: Maturity Model Phase Overview

5.2 IoT Challenges: Utilizing Strengths and Overcoming Weaknesses

As a business navigates through the phases of implementation and levels of connectivity, it is bound to encounter some of the common challenges businesses face when introducing IoT technologies. The next several sections will address each challenge with consideration of the common strengths and weaknesses of the small to medium sized business. In this way, the model intends to highlight the competitive advantage of the SMB in IoT implementation.

5.2.1 Security

The most relevant weakness for security challenges for the SMB is a lack of qualified personnel to design and maintain secure information systems. A study conducted by Nieto and Santamaria found that the SMB would benefit from technological collaboration to help bridge the organizational gaps preventing technological growth (Nieto & Santamaria, 2010). The study concluded that through collaboration, the SMB artificially creates some of the resource and material advantages of a larger organization while still maintaining the behavioral advantages of being smaller. The SMB must collaborate with other organizations that have the expertise they lack, until they are able to develop the capabilities internally, if needed. This is one of many reasons why the four phases of the maturity model progress in reach gradually. As the SMB becomes proficient at securing non-sensitive internal process data by developing a thorough risk management program, the systems can be expanded to include anything from intellectual property to customer personally identifiable information (PII).

Navigating through the security challenges brought on by IoT is made possible through an incremental and continuous risk assessment process (Grobauer, Walloschek, & Stocker, 2011). Companies must not allow their systems to grow without an understanding of where the system vulnerabilities are or without a plan to mitigate the risks associated with those vulnerabilities. Risk management strategies for IoT security threats is no different than any other risk management strategy in that it requires regular monitoring and re-assessment, accompanied by a security response that is proportional to the size of the threat and the value of the at-risk information.

Finally, some of the other most commonly found it literature ways to prevent or reduce the impact cybersecurity attacks are the following:

1) Train employees on best security practices
2) Proper use of encryption
3) Select devices and hardware capable of remote updating and keep them up to date
4) Making hardware tamper resistant
5) Redundancy of critical systems

5.2.2 Data Reliability

A commonly cited concern in the implementation of IoT is data reliability. Big data offers many opportunities while simultaneously presenting many new problems. The phased implementation helps to address this issue by trying to prevent data from outgrowing the business processes, software, and people needed to transform that data into decision-making fodder.

5.2.3 Culture

Lean and six sigma organizations have an advantage, already having done a lot of the "culture work" required to create open, process-improvement focused minds. The SMB has similar advantages, in that culture changes comes much easier for smaller organizations than larger organizations, assuming that the overall goals and values of the organizations remain intact throughout the process. The SMB might already have a combined IT and OT organization, and may have already adopted non-proprietary systems in order to compensate for lack of technical manpower. The leadership of an SMB innately requires more flexibility, as organizations of this size are expected to be responsive to changes in the market and environment. The SMB will increase their likelihood of success by being fully transparent with stakeholders, customers, suppliers, etc. in the full extent of their implementation of the Internet of Things. The phased approach of this model will facilitate this process, as the open systems can be used and tested internally before being exposed to external suppliers and customers.

5.3 The Phases

5.3.1 Phase 1

One potential threat for an organization in the early stages of implementing the Internet of Things is the threat of heading in the wrong direction from the start (Vavra, 2015). Therefore, the first phase of the maturity model does not confine the organization to one direction, but instead allows for the introduction of IoT concepts without a large capital investment or complex strategic plan. In addition, the survey results in the previous chapter indicated that small to midsize businesses see return on investment, ROI, as a major barrier to implementing IoT in their organizations. Phase 1 provides an opportunity for the business to test IoT concepts, ideally in the areas of their business in which it could have the largest impact.

Phase 1, therefore, begins small, with the implementation of "IoT in a box" solutions that have the following characteristics:

1) The solution solves a real, quantifiable problem.
2) The solution does not require extensive redesign of existing processes.
3) The solution can be installed within defined boundaries to prevent scope creep.

   OR

   The solution can be implemented using existing sensor network and hardware

A key component of the first phase is avoiding the temptation to unsystematically add a large number of sensors and actuators without a specific driver. Choosing a solution that utilizes existing sensors or requires minimal additional hardware is therefore ideal. However, setting boundaries to the project and installing sensors within the original planned scope also helps to prevent creating an unmanageable pilot. Organizations might come into Phase 1 having already implemented M2M technologies in their facility, and in this case, the pilot might involve taking two individual sensor networks and placing them on the same network so that the data make work collaboratively. Also, the top IoT applications being used by the respondents of the survey from Chapter 3 and 4 were smart lighting, waste management solutions, intrusion detection systems, and temperature monitoring systems. In practice, it would seem these four areas are some of the first targeted, most likely due to the ease of finding IoT products and ease of implementation. Therefore these four areas could be good candidates for a Phase 1 pilot.

Having all the aforementioned characteristics help to create a manageable scope for an IoT pilot. However, in the selection of IoT products, a business must also consider the product's capability. Considering the "smart" product capability diagram from the previous section, the first two categories are appropriate in scope for a Phase 1 pilot, while Phase 2 would better allow the introduction of products from categories 3 and 4, depending on the starting point of an individual business. Once the scope of the project has been determined and the desired IoT product or product candidates have been chosen, a cost benefit analysis can be performed to pre-test the project's outcome and help with product selection.

Again, one of the major goals of Phase 1 is to confirm the Return on Investment (ROI) of IoT applications in the company. In addition to addressing one of the top barriers identified for IoT implementation, it also presents the opportunity to trigger a change in the culture. The project provides an opportunity both for management to monitor and test the decision making skills of the workforce and for the workforce to gain confidence in data-driven decision making in a controlled environment.

Dovere, Cavalieri and Ierace of the University of Bergamo outlined a case study that illustrates this phase of IoT implementation involving the deployment of RFID tags on machine tools in an industrial environment (Dovere, Cavalieri, & Ierace, 2015). The study describes going through the process of an AS-IS analysis, to identify the opportunities that would be provided by implementing RFID. Some of the inefficiencies identified include manual identifying and physically searching for and locating needed tools from reading a tool program. Often times the wrong tools were selected, or tools would be found already placed on other pieces of equipment. The study determined that RFID implementation would allow improvements including but not limited to a 20% reduction in tools, a 50% reduction in accidental events, a 50% reduction in scrap, and a 33% increase in units manufactured. The overall equipment effectiveness (OEE) increase in the study was 34%.

5.3.2 Phase 2

After the successful completion of a pilot and some validation of the ROI for IoT, a company can begin identifying other internal areas of the business as candidates to include in the network. Techniques such as Value Stream Mapping can be used to identify the bottlenecks that might benefit the most from automation. Targeted areas might have results that include but are not limited to labor reduction, cost reduction, error reduction, increased speed and quality of decision-making and improved productivity. At this point, a company should begin to feel more comfortable making larger investments in IoT technologies, however, a successful Phase 1 pilot can potentially provide enough additional capital for reinvestment into Phase 2.

For an organization that does not already have sensor networks in place, obvious candidates for sensors could include any physical monitoring currently performed by personnel. Sensors can provide quick return on investment upon replacement of in-person monitoring. However, an organization must keep in mind, when introducing sensor networks, of the end purpose of the data. For example, a sensor network should be set up in a way that provides the exact information an employee would need to act on the information, so that when that information begins to move out of the organization and into a connected platform, the data being collected will already contain exactly what is needed to make decisions. In order to avoid the data overload that happens when IoT technologies are deployed, it is important to understand where the data needs to go in order to be useful. Each employee should not be provided with more information than what they need to make effective decisions. Information overload simply clouds an individuals' ability to make decisions (Godfrey, Gryz, & Lasek, 2016). This phase, therefore, is a good time to introduce data analytics and visualization software into the process. Another essential piece of the implementation of IoT is not only to provide employees with data and information, but also to provide them with the power to act on that data (Vavra, 2015). A critical step in this phase is for an organization to evaluate its decision-making culture.

The SMB might consider engaging a consultant in this phase, who, in addition to assisting with IoT implementation and the introduction of analytics software, can assist with the creation of a staffing plan needed to fill the talent gaps for IoT implementation. As addressed in Section 5.2, the SMB must rely on collaboration to fill gaps until it become beneficial to acquire those skill in house.

5.3.3 Phase 3

Phase 3 of the implementation model assumes that a company is comfortably supporting IoT implementation internally, including appropriate staffing changes proposed in the previous phases or having filled skill gaps with semi-permanent collaborative relationships. At this point, the organization can comfortably consider how to incorporate suppliers or other partners into their sensor network. Whether it be through sharing inventory levels with a supplier to sharing equipment status with the company who supports maintenance activities. This phase is also an opportunity to evaluate suppliers and partners, and potential re-select and re-align with organizations who are prioritizing data-driven decision making in their operations.

5.3.4 Phase 4

Up until this point, IoT applications have primarily been limited to those that solve business problems, optimize processes, improve communication, and so on. In Phase 4, a company reaches a stage in which they are ready to begin seeking out new opportunities using this technology. For the small to medium sized business, one study found that finding such opportunities does not require entrepreneurial thinking, but instead relies upon innovative individuals with managerial competence (Hulbert, Gilmore, & Carson, 2015). By Phase 4, these individuals should be sprinkled throughout the workforce, ready to identify new prospects. Boer and Gertsen emphasize that a business must utilize what they coin *continuous innovation* in order to maximize the potential of combining operational effectiveness and strategic flexibility (Boer & Gertsen, 2003).

Phase 4, however, is primarily defined by the companies' ability to design IoT capabilities into their products or into devices that allow them to begin engaging their customers directly and in real time. For this, the SMB may have an advantage, given their customeroriented nature. The following example demonstrates the importance of reaching a certain level of competence and IoT saturation internally prior to rolling out IoT capabilities or technologies to customers.

Adam Bosworth, executive vice president of Saleforce.com's IoT cloud, illustrated the danger of pushing IoT applications to the customer before the company has adopted these applications internally in an anecdotal but demonstrative story about his wife (Leary, 2016). His example involved her "connected vehicle" being unable to provide her any value beyond that of a "disconnected" vehicle. When her engine light came on, instead of the dealer being alerted to her issue and pushing suggestion to open slots on her calendar for repair, she instead spent a lot of time reaching out to the company herself only to receive a two week expected lead time for repair. Her frustration then outweighed any delight she had in the additional features of her vehicle, leaving her with a more negative impression than if the features had never existed in the first place. This example demonstrates the importance of having established IoT application internally and with suppliers, as outlined in Phases 1 to 3, prior to engaging the customer directly with IoT technologies. This is especially important for the SMB in order to properly take advantage of the strength of customer engagement outlined earlier in the chapter.

Chapter 6: Conclusion

6.1 Research Questions Addressed

This research attempted to compile some of the known applications and challenges of IOT and seek out answers to questions surrounding the awareness and use of IoT by the SMB. This research included literature research and analysis of direct input from SMB owners, executives, and other engaged employees. The compilation concluded with a proposed future direction in the form of the "Internet of Things Maturity Model", in which the SMB can evaluate their current state, utilize their strengths, overcome their weaknesses and begin to take advantage of the benefits IoT can bring to an organization.

The research suggests that IoT is indeed relevant and useful for small to medium sized businesses. The literature review identified potential opportunities including remote monitoring and control, real time optimization, mass customization, big data and analytics, and enhanced customer relationships. From the survey, the majority of respondents indicated that they were already using or interested in IoT technologies and applications and the majority also identified specific benefits. The top IOT applications and technologies that are being used or that SMBs are interested in provide some insight into how IoT is useful for them. According to the respondents, they believe the greatest benefits of IoT would be cost efficiencies, better streams of data, and better customer experiences. In addition, the survey results demonstrated that SMBs have an overall positive impression of IoT, especially when made aware of its benefits and applications.

Implementation of the Internet of Things comes with many challenges and potential barriers to entry. The literature search identified security challenges as well as culture challenges including IT/OT merge, open standards, and workforce adaptations. When survey respondents were asked about the biggest barriers they listed return on investment, lack of internal IT expertise, integrating IoT with current systems, and security risks.

The strengths and weaknesses of the SMB were identified, and their relevance to IoT implementation was evaluated. The primary weaknesses affecting these businesses' ability to implement IoT are qualified staff and capital resources. However, these weaknesses can be overcome through the strategic use of collaboration and an ROI-focused implementation approach. Implementing IoT, however, requires many of the qualities that are strong in most SMBs including a dynamic environment, flexible leadership, customer orientation and strong interfunctional coordination.

Overall, although in some ways at a disadvantage to larger corporations in the implementation of IoT, SMBs should not be afraid to pursue IoT technologies, especially if they are willing to rely on their strengths in its successful implementation.

6.2 Areas for Further Study

The literature on how the Internet of Things (IoT) will impact small to midsize businesses (SMBs) is very limited and therefore further study including larger surveys and in depth case studies should be conducted to better understand the current landscape. The general model for implementation outlined in Chapter 5 needs further development by partnering and receiving feedback from small and medium sized businesses to improve its specific applicability and to prime for validation and testing.

Follow-up questions were generated as the research was conducted, including:

- What is the relationship between IoT and innovation?
- Is there a relationship between the value of IoT and firm size?

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Appendices

Appendix A: Survey Questions

How many persons are employed at your company?

- ☐ 1
- ☐ 2-9
- ☐ 10-24
- ☐ 25-99
- ☐ 100-499
- ☐ 500-999
- ☐ 1,000-4,999
- ☐ 5,000+

In what industry does your company or organization operate?

- ☐ Healthcare
- ☐ Manufacturing
- ☐ Education (K-12)
- ☐ Higher Education
- ☐ Banking/Finance
- ☐ Insurance
- ☐ Communications
- ☐ Transportation
- ☐ Government
- ☐ Retail
- ☐ Hospitality
- ☐ Non-Profit

What percentage of work at your company is done on mobile devices or tablets?

- ☐ 0 - 10%
- ☐ 11 - 25%
- ☐ 36 - 50%
- ☐ 51 - 75%
- ☐ 76 – 100%

What is your overall general impression when you hear the term "Internet of Things" in the context of your company? (CompTIA, 2016)

☐ Definitely will provide value

☐ Might provide value

☐ Will not provide value

☐ Likely a distraction from core business

☐ I'm not sure what it is

Select the appropriate choice for each IoT technology as it applies to your company:

	Currently Using	Would Like to Use	Uninterested	Not Applicable
Radio-Frequency Identification (RFID)	☐	☐	☐	☐
Wireless Sensor Networks (WSNs)	☐	☐	☐	☐
Cloud Computing	☐	☐	☐	☐
Near Field Communication (NFC)	☐	☐	☐	☐
Low Energy Bluetooth	☐	☐	☐	☐
Low Energy Wireless	☐	☐	☐	☐
Radio Protocols (e.g. Zigbee)	☐	☐	☐	☐
LTE-A	☐	☐	☐	☐
Wifi Direct	☐	☐	☐	☐
Wearables	☐	☐	☐	☐

Select the best choice for each IoT application as it applies to your company:

	Currently Using	Would Like to Use	Uninterested	Not Applicable
Structural Health Vibration and material monitoring in buildings	☐	☐	☐	☐
Smart Lighting Power consumption management	☐	☐	☐	☐
Waste Management Detection of waste levels in containers for optimization	☐	☐	☐	☐
Area Access Control Controlling access to restricted areas	☐	☐	☐	☐
Liquid Detection Detection of liquid levels in sensitive areas	☐	☐	☐	☐
Radiation Level Detection Distributed measurement of radiation levels to generate alerts	☐	☐	☐	☐
Hazardous Gas Detection Detection of gas levels and leakages	☐	☐	☐	☐
Consumer Monitoring at Point of Sale Customer habits, preferences	☐	☐	☐	☐
Smart Product Management Control of product rotation, restocking automation	☐	☐	☐	☐
Shipment monitoring Monitoring of vibrations, strokes, containers openings	☐	☐	☐	☐
Product Tracking for traceability Search of individual items in large areas such as warehouses	☐	☐	☐	☐
Storage Incompatibility Detection Alerts on incompatible containers (inflammable and explosive)	☐	☐	☐	☐
M2M Machine and asset auto-diagnosis and control	☐	☐	☐	☐
Indoor Air Quality Monitoring of gas levels relevant for worker safety	☐	☐	☐	☐
Temperature Monitoring Control of temperature in sensitive areas	☐	☐	☐	☐
Indoor Location Asset location with tags	☐	☐	☐	☐
Energy and Water Use Supply consumption monitring for resource optimization	☐	☐	☐	☐
Remote Control Appliances Remote control to save energy and avoid incidents	☐	☐	☐	☐
Intrusion Detection Systems Detection of entryway disturbances	☐	☐	☐	☐

Having read over some of the potential applications for the Internet of Things, please answer the following question once more:

What is your overall general impression when you hear the term "Internet of Things" in the context of your company? (CompTIA, 2016)

- ☐ Definitely will provide value
- ☐ Might provide value
- ☐ Will not provide value
- ☐ Likely a distraction from core business
- ☐ I'm not sure what it is

What do you believe are the top three biggest barriers to implementing IoT in your organization or company?

- ☐ Difficulty integrating Information Technology (IT) with Operations Technology (OT)
- ☐ Lack of internal IT expertise to implement and operate
- ☐ Legal, Regulatory or Compliance
- ☐ What to do with all the "data"
- ☐ Security Risks
- ☐ Return on Investment
- ☐ Integrating IoT solutions with current systems and processes (Compatibility)
- ☐ Lack of open standards
- ☐ Stakeholder buy-in
- ☐ Network constraints
- ☐ Culture change
- ☐ Other: _________________________

What benefit of IoT do you view to be the most valuable for your organization? (CompTIA, 2016)

- ☐ Cost savings from operational efficiency gains
- ☐ New and/or healthier streams of data to improve decision-making
- ☐ Workforce productivity gains
- ☐ Better visibility and monitoring of assets throughout the organization
- ☐ New and/or improved customer experiences
- ☐ Other: _________________________

To what level is your company working to incorporate the "Internet of Things" into business processes or products? (CompTIA, 2016)

- ☐ Formal IoT initiative underway
- ☐ IoT pilot project underway
- ☐ In the planning and preparation stage
- ☐ No immediate plans to integrate with IoT

What cybersecurity solutions are implemented at your company?

- ☐ Internal Solutions
- ☐ 3rd party solutions
- ☐ No solutions
- ☐ I don't know

Has your company ever been a victim to a cyber-attack?

- ☐ Yes, multiple times
- ☐ Yes, once
- ☐ No
- ☐ I don't know

Optional: *Please describe your company's current experience with the Internet of Things including current knowledge, strategy, implementation woes, and/or future plans.*

Appendix B: Complete Survey Results

What is your role?		
Answer Choices	**Responses**	
Supervisor	1.64%	1
No Response	1.64%	1
Individual Contributor	4.92%	3
Manager	13.11%	8
Director	16.39%	10
Executive	21.31%	13
Owner	40.98%	25

How many employees work for your company/organization?		
Answer Choices	**Responses**	
1	4.92%	3
500-999	6.56%	4
100-499	14.75%	9
10-24	22.95%	14
25-99	24.59%	15
2-9	26.23%	16

In what industry does your company or organization operate?		
Answer Choices	**Responses**	
Arts/Sports/Entertainment	1.64%	1
Communications	1.64%	1
Government	1.64%	1
Healthcare	1.64%	1
Transportation	1.64%	1
No Response	1.64%	1
Hospitality	3.28%	2
Retail	3.28%	2
Energy	4.92%	3
Business Serv., Consulting, & Mngmt	9.84%	6
Technology	13.11%	8
Other	16.39%	10
Manufacturing	39.34%	24

What is your overall impression when you hear the term "Internet of Things" in the context of your company or organization? (Pre-Survey)		
Answer Choices	**Responses**	
Will not provide value	6.56%	4
Likely a distraction from core business	11.48%	7
I'm not sure what it is	18.03%	11
Might provide value	29.51%	18
Definitely will provide value	34.43%	21

Please characterize the use of each of the following IoT technologies in your company or organization:									
Technology	**Currently Using**		**Would Like to Use**		**Uninterested**		**N/A**		**Total**
Radio-Frequency Identification (RFID)	21.05%	12	33.33%	19	29.82%	17	15.79%	9	57
Wireless Sensor Networks (WSNs)	24.56%	14	29.82%	17	31.58%	18	14.04%	8	57
Cloud Computing	61.40%	35	22.81%	13	14.04%	8	1.75%	1	57
Near Field Communication (NFC)	9.09%	5	27.27%	15	38.18%	21	25.45%	14	55
Low Energy Bluetooth	30.36%	17	26.79%	15	26.79%	15	16.07%	9	56
Low Energy Wireless	36.84%	21	24.56%	14	24.56%	14	14.04%	8	57
Radio Protocols (e.g. ZigBee)	8.93%	5	17.86%	10	42.86%	24	30.36%	17	56
LTE-A	9.43%	5	16.98%	9	33.96%	18	39.62%	21	53
Wi-Fi Direct	47.37%	27	14.04%	8	21.05%	12	17.54%	10	57
Wearables	26.42%	14	32.08%	17	30.19%	16	11.32%	6	53

	Currently Using	Would Like to Use	Uninterested	N/A
Radio-Frequency Identification (RFID)	21%	33%	30%	16%
Wireless Sensor Networks (WSNs)	25%	30%	32%	14%
Cloud Computing	61%	23%	14%	2%
Near Field Communication (NFC)	9%	27%	38%	25%
Low Energy Bluetooth	30%	27%	27%	16%
Low Energy Wireless	37%	25%	25%	14%
Radio Protocols (e.g. Zigbee)	9%	18%	43%	30%
LTE-A	9%	17%	34%	40%
Wifi Direct	47%	14%	21%	18%
Wearables	26%	32%	30%	11%

Figure B.1 IoT Technology Use and Interest Color Coded

Please characterize the use of each of the following IoT applications in your company:				
	Currently Using	**Would Like to Use**	**Uninterested**	**N/A**
Structural Health	6	9	22	15
Smart Lighting	16	20	9	8
Waste Management	3	18	19	13
Area Access Control	14	22	8	9
Liquid Detection	6	12	17	18
Radiation Level Detection	3	4	21	25
Hazardous Gas Detection	8	11	15	19
Consumer Monitoring	8	18	14	12
Smart Product Management	9	23	13	8
Shipment monitoring	5	21	12	16
Product Tracking	11	18	13	11
Storage Incompatibility Detection	0	11	21	20
M2M Applications	7	11	15	18
Indoor Air Quality	5	16	14	17
Temperature Monitoring	13	12	15	12
Indoor Location	2	18	16	16
Energy and Water Use	5	22	14	11
Remote Control Appliances	8	19	13	12
Intrusion Detection Systems	19	14	9	9

Application	Currently Using	Would Like to Use	Uninterested	N/A
Structural Health Vibration and material monitoring in buildings	12%	17%	42%	29%
Smart Lighting Power consumption management	30%	38%	17%	15%
Waste Management Detection of waste levels in containers for optimization	6%	34%	36%	25%
Area Access Control Controlling access to restricted areas	26%	42%	15%	17%
Liquid Detection Detection of liquid levels in sensitive areas	11%	23%	32%	34%
Radiation Level Detection Distributed measurement of radiation levels to generate alerts	6%	8%	40%	47%
Hazardous Gas Detection Detection of gas levels and leakages	15%	21%	28%	36%
Consumer Monitoring at Point of Sale Customer habits, preferences	15%	35%	27%	23%
Smart Product Management Control of product rotation, restocking automation	17%	43%	25%	15%
Shipment monitoring Monitoring of vibrations, strokes, containers openings	9%	39%	22%	30%
Product Tracking for traceability Search of individual items in large areas such as warehouses	21%	34%	25%	21%
Storage Incompatibility Detection Alerts on incompatible containers (inflammable and explosive)	0%	21%	40%	38%
M2M Applications Machine and asset auto-diagnosis and control	14%	22%	29%	35%
Indoor Air Quality Monitoring of gas levels relevant for worker safety	10%	31%	27%	33%
Temperature Monitoring Control of temperature in sensitive areas	25%	23%	29%	23%
Indoor Location Asset indoor with tags (active and passive)	4%	35%	31%	31%
Energy and Water Use Supply consumption monitoring for resource optimization	10%	42%	27%	21%
Remote Control Appliances Remote control to save energy and avoid incidents	15%	37%	25%	23%
Intrusion Detection Systems Detection of entryway disturbances	37%	27%	18%	18%

Figure B.2 IoT Applications Use and Interest Color Coded

What benefit of IoT do you view to be the most valuable for your organization? (CompTIA, 2016)		
Answer Choices	**Responses**	
Workforce productivity gains	7.41%	4
Other	7.41%	4
Better visibility and monitoring of assets	9.26%	5
No Response	11.11%	6
New and/or improved customer experiences	16.67%	9
New and/or healthier streams of data to improve decision-making	20.37%	11
Cost savings from operational efficiency gains	27.78%	15

What is your overall impression when you hear the term "Internet of Things" in the context of your company?(Post-Survey)		
Answer Choices	**Responses**	
Will not provide value	3.70%	2
Likely a distraction from core business	7.41%	4
I'm not sure what it is	7.41%	4
Might provide value	35.19%	19
Definitely will provide value	46.30%	25

What do you believe are the top three biggest barriers to implementing IoT in your organization or company?		
Answer Choices	**Responses**	
Legal, Regulatory or Compliance	3.70%	2
Lack of open standards	7.41%	4
Network constraints	7.41%	4
Other	7.41%	4
No Response	12.96%	7
Stakeholder buy-in	18.52%	10
Culture change	20.37%	11
Difficulty integrating IT with OT	22.22%	12
What to do with all the "data"	24.07%	13
Security Risks	25.93%	14
Integrating IoT solutions with current systems	29.63%	16
Lack of internal IT expertise to implement and operate	37.04%	20
Return on Investment	46.30%	25

To what level is your company working to incorporate the "Internet of Things" into business processes or products? (CompTIA, 2016)		
Answer Choices	**Responses**	
IoT pilot project underway	5.56%	3
Formal IoT initiative underway	7.41%	4
No Response	7.41%	4
Planning and preparation stage	29.63%	16
No immediate plans to integrate with IoT	50.00%	27

What percentage of work at your company is done on mobile devices or tablets?		
Answer Choices	**Responses**	
51 - 75%	7.41%	4
76 – 100%	11.11%	6
36 - 50%	12.96%	7
0 - 10%	29.63%	16
11 - 25%	38.89%	21

What cybersecurity solutions are implemented at your company?		
Answer Choices	**Responses**	
Other	3.70%	2
No solutions	9.26%	5
I don't know	16.67%	9
Internal Solutions	29.63%	16
3rd party solutions	40.74%	22

Has your company ever been a victim to a cyber-attack?		
Answer Choices	**Responses**	
No Response	5.56%	3
Yes, multiple times	11.11%	6
Yes, once	12.96%	7

I don't know	16.67%	9
No	53.70%	29

Optional: Please describe your company's current experience with the Internet of Things including current knowledge, strategy, implementation woes, and/or future plans.
Mostly designing IoT products for other companies.
We plan on finding out more information on this and to see if it will benefit our company
Company name removed, LLC is a fledgling company with a single product expecting to roll out within 60 days. Many of the IoT items listed here are far away from what we would or could do, but I recognize the value of connectivity between processes, information management, product delivery and the consumer experience. We hope to get there.
IoT is not on our radar.
New web platform coming soon
Creating sensors for IoT
It will revolutionize both manufacturing of our equipment and the aftermarket care of the equipment. Will be big bucks in all parts of company operations and for customers.
No past experience and no current plans.
We are planning to use the IoT to provide fleet management, diagnostics, and tracking for both internal and external customers.
No real working knowledge or short term integration objectives.
We are currently focusing more on mobile workforce technology and improving enterprise systems.
No ROI for implementing into our location
Very willing, but stymied by regulatory/security concerns at primary work site.
n/a we ae a remote business for the most part
We are a data analytics consulting form that help companies plan data strategy opportunities to leverage IoT within their enterprise.

IoT Perception Pre- and Post- Survey Coded Comparison			
ID	**Before**	**After**	**Change**
6459710422	Definitely will provide value	Definitely will provide value	No Change
6456973500	Might provide value	Might provide value	No Change
6456922909	I'm not sure what it is	Definitely will provide value	Positive
6456418077	Definitely will provide value	Definitely will provide value	No Change
6455052464	Might provide value	Definitely will provide value	Positive
6454972950	Definitely will provide value	Might provide value	Negative
6454895394	I'm not sure what it is	I'm not sure what it is	No Change
6454658256	Might provide value	Might provide value	No Change
6454579031	Might provide value	Might provide value	No Change
6454221101	I'm not sure what it is	I'm not sure what it is	No Change
6453223634	Might provide value	Might provide value	No Change
6453215800	Likely a distraction from core business	I'm not sure what it is	Negative
6451923217	Might provide value	Might provide value	No Change
6451380465	Might provide value	Definitely will provide value	Positive
6450684291	Definitely will provide value	Definitely will provide value	No Change
6450409363	Definitely will provide value	Definitely will provide value	No Change
6450241249	I'm not sure what it is	Definitely will provide value	Positive
6449541478	Might provide value	Definitely will provide value	Positive

6448912782	Definitely will provide value	Definitely will provide value	No Change
6448263214	Might provide value	Might provide value	No Change
6448237125	Will not provide value	Might provide value	Positive

ID	Before	After	Change
6448220844	Definitely will provide value	Definitely will provide value	No Change
6441805050	Definitely will provide value	Definitely will provide value	No Change
6441706739	Definitely will provide value	Definitely will provide value	No Change
6441130404	Likely a distraction from core business	Might provide value	Positive
6438721597	I'm not sure what it is	Might provide value	Positive
6438661772	I'm not sure what it is	Might provide value	Positive
6438339734	Might provide value	Might provide value	No Change
6437793697	Definitely will provide value	Definitely will provide value	No Change
6436979579	I'm not sure what it is	Likely a distraction from core business	Negative
6436361901	Likely a distraction from core business	Likely a distraction from core business	No Change
6436197070	Might provide value	Might provide value	No Change
6436028886	Definitely will provide value	Definitely will provide value	No Change
6435916375	Will not provide value	Will not provide value	No Change
6433044386	Might provide value	Might provide value	No Change
6430209698	Likely a distraction from core business	Likely a distraction from core business	No Change
6426939092	Definitely will provide value	Definitely will provide value	No Change
6426505898	Might provide value	Might provide value	No Change
6421851431	Definitely will provide value	Definitely will provide value	No Change
6421482901	Definitely will provide value	Definitely will provide value	No Change
6418256200	Likely a distraction from core business	Likely a distraction from core business	No Change
6416315600	I'm not sure what it is	Might provide value	Positive
6416059397	Definitely will provide value	Definitely will provide value	No Change
6416019479	Might provide value	Definitely will provide value	Positive
6415355045	Might provide value	Might provide value	No Change
6415225948	Definitely will provide value	Definitely will provide value	Positive
6414528296	Definitely will provide value	Definitely will provide value	No Change
6413672018	Might provide value	Might provide value	No Change
6412994089	Definitely will provide value	Definitely will provide value	No Change
6412868088	Definitely will provide value	Definitely will provide value	No Change
6411549266	I'm not sure what it is	I'm not sure what it is	No Change
6411379184	Definitely will provide value	Definitely will provide value	No Change
6410131468	Will not provide value	Will not provide value	No Change

Vita

Amanda Smart was born in Franklin, TN and raised by her loving mother and her persuasive father, a fellow industrial engineer. Upon high school graduation, she moved to Knoxville, TN where she would spend the next ten years, completing her Bachelor's degree in Industrial Engineering before beginning employment at the Y-12 National Security Complex in Oak Ridge, TN. Her roles at Y-12 have spanned from operations support specialist to scheduling lead to business programs analyst to her current role as the Continuous Improvement Lead for the Production organization. Last year, Amanda participated in a Dale Carnegie leadership course and received the Highest Award for Achievement. Amanda graduated with her Master of Science in Industrial Engineering in the Fall of 2017. She has recently moved to Atlanta, GA to be with her new husband and pursue new career opportunities.