Value Creation from the Internet of Things in Heavy Machinery: A Middle Manager Perspective

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Abstract We develop a novel understanding of value creation from the Internet of Things (IoT) in the heavy machinery industry. We analyze the operational middle management perspective on the current state of IoT implementation in four industry segments utilizing heavy machinery, including chemicals, electrical equipment, marine, and pulp and paper. We find four value drivers from IoT (product optimization, maintenance and recovery optimization, energy efficiency, and safety improvements) that pertain to the underlying joint value driver of predictability with operating heavy machinery. Furthermore, we outline current core issues and constraints in IoT data utilization and value realization in the heavy machinery industry. Our findings expose how middle managers recognize high value potential from IoT implementation but indicate only gradual value capture if data gathering, knowledge sharing, and data analytics are not improved. Architectural transformation programs that include establishing knowledge-sharing hubs and connected expertise between organizational units, external experts, and suppliers are needed to unlock the full novel value-creation potential of the IoT in heavy machinery.

Keywords Value creation · Internet of things · Heavy machinery · Middle manager

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Introduction

The Internet of Things (IoT) is emerging as a novel source of value creation in heavy machinery. IoT technologies allow for the real-time connectivity and interconnection of devices in the cloud, which generates aggregated data from the application and usage of the devices through sensors (e.g., Porter and Heppelmann 2014; Atzori et al. 2017). IoT technologies are placed in the machinery and production facilities. IoT holds the potential to change the underlying economics of processes and operations of those firms that utilize and deliver heavy machines, technologies, and services. The industry architecture is defined as the division of labor between firms in an industry encompassing the physical and technical architecture (Jacobides et al. 2006). The architectures of these industries are currently in a state of flux where new business models, new types of relationships between firms, and novel entrant engagements are being explored. In recent years, the enabling technological conditions for IoTs (including sensors, communication, software, and data analytics) have become more favorable with decreasing costs and performance advancements (Atzori et al. 2010, 2017; Evans and Annunziata 2012).

The IoT allows industrial firms to enhance their existing value creation through increased productivity. The IoT allows for the capturing of data from machines, aggregating information across networks and either taking immediate action based on the data or gradually learning more about the processes (Manyika et al. 2015). This allows firms to remotely control and monitor machines and factory operations, increase automatization, and optimize machine use, factory operations, inventory, and supply chain management. Novel, big datasets, real-time connectivity, data analytics, and processing algorithms have the potential to create intelligent production and machine systems. Machine monitoring, control, and optimization can become increasingly autonomous, where machines learn about their environment, self-diagnose service needs, and adapt to a user's preferences (Porter and Heppelmann 2014). Overall, the efficiency gains through which the IoT can realize are increased production uptime, improved asset utilization, decreased energy consumption, better operational safety, and transparent, coherent processes.

The IoT in heavy machinery applications changes existing B2B industrial customer relationships from turn-key solution deliveries and after-sales service relationships toward an "online relationship." The suppliers and customers are becoming more closely connected to each other through data and remote connections (Porter and Heppelmann 2014). In-depth knowledge of customer systems enables suppliers to service their customers in real time, offer additional products and services, and customize offerings. In addition, the closer supplier-customer relationship has the potential to increase cooperation in product development and create faster product development cycles. Understanding value creation processes from the customer point of view allows firms to generate greater levels of customer satisfaction, loyalty, and repurchase behavior and to create a lock-in to the supplier (Bradley et al. 2013).

Middle managers are defined as “any manager two levels below the CEO and one level above line workers and professionals” (Huy 2001: 73). They are critical in IoT adaptation and implementation. They have a strong understanding and knowledge of the firm operations, access to the top management, and unique positions to leverage informal networks of the firm (Huy 2001; Balogun 2003). Therefore, middle managers can bridge continuity and change (Huy 2001). In addition, they are central actors that interpret and sell change in the firm (Rouleau 2005). They are intermediates between disconnected actors, domains, levels, and units in the firm and act as mediators between firm strategy and day-to-day activities (Wooldridge et al. 2008). The intermediating role includes influencing outcomes and interpreting strategy both upward and downward in an organizational hierarchy, thus making middle managers important actors in both strategy formulation and implementation.

IoT solutions have not yet been widely adopted and capitalized upon (Accenture 2015b), even though the substantial long-term benefits are acknowledged by top management (Koch et al. 2014; PwC 2015), and the enabling technological conditions already exist (Atzori et al. 2017). Currently, only a fraction (approximately 1%) of existing IoT data is utilized (Manyika et al. 2015). The early technological applications of the IoT have been put in place in many industries, and top management vision is supporting further advancements. Further utilization of the potential of the IoT has more to do with operational and organizational practice transformation and strategy implementation than the technological conditions or generic strategic vision shared by top managers. As such, there is limited understanding on how the data gathered from the machinery could enhance value creation from the perspective of middle managers. Furthermore, there are inadequate foundations for implementing the IoT-related systems, practices, and services. Hence, in order to study IoT-based value creation in the heavy machinery industry, we assess the IoT-related key value realization constraints and drivers from the perspective of middle managers. This allows us to both uncover the current middle management perspective of IoT and formulate managerial implications for future IoT strategies in the heavy machinery industry.

Study, Data, and Methods

We study the middle management perspective on value creation from IoT in the context of four industry segments utilizing heavy machinery (chemicals, electrical equipment, marine, and pulp and paper). Our data sample includes one sample firm from each of the studied industry segments (in total four firms) in which heavy machinery is critical to value creation. The case firms were deliberately chosen because the firms had not implemented full-scale IoT solutions, but they had interest in and plans for a wider implementation of and more investments in the IoT. Since there is a limited amount of research on IoT implementation and especially on the middle manager perspective on IoT value creation, we chose an inductive qualitative study design aimed at building a new theoretical understanding rather than

Table 1 List of interviewees

Industry	Area of responsibility
Chemicals	Maintenance manager
	Electrical maintenance manager
	IT manager
	Electricity and automation engineer
	Electricity work planner
Electrical equipment	Unit manager, unit A
	Unit manager, unit B
	Plant manager, production manager
	Operations manager
	Quality manager
Marine	Captain
	Chief engineer
	Operations manager
	Electricity manager
Pulp and paper	Plant manager
	Production manager
	Maintenance manager
	IT manager, factory A
	IT manager, factory B
	Development manager
	Planning manager

testing or elaborating on constructs (Gioia et al. 2013). Our approach seeks to obtain a novel understanding of the IoT value drivers in heavy machinery by engaging with the organizational actors experiencing the phenomenon of interest. Using semi-structured interviews, in 2016, we engaged with middle management (operations and product management) in each of the case firms. We conducted a total of 21 interviews (for a list of interviewees, their positions, and the respective case firms' industries, see Table 1).

The interviews were conducted in Finland, although the middle managers' companies all operated in multiple countries. We complemented our interview data with observations by attending six IoT industry events during our data collection process, all during 2016.

We analyzed the data collected from the interviews with comprehensive qualitative coding using Atlas.TI. In the analysis process, we used the interview data to form first-order concepts. After careful deliberation with the research team, we grouped these into second-order themes that highlighted key dimensions arising from the interview data (Gioia et al. 2013). To verify our findings and build managerial implications, we continuously reanalyzed our results, the prior research, and the industry event observation data until additional rounds did not provide further insights. From this process, we were able to extract our main empirical findings in aggregated dimensions, including the present state of data use in value creation in

Table 2 Present state of data use in heavy machinery

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Data abundance	High amount of data from automation	"We have basic measurements that we need in our automation system about flows, temperature, pressure, frequency and paper and board quality-related ones that tell, for example, square weights, humidity, calibers and fiber electrical attributes. We try to measure everything that is reasonably measurable." – *IT Manager, Factory A, Pulp and Paper*
	Too much information	"We already have too much information from the automation system to our operational employees, but, on the other hand, this information could be used better when disturbances occur so that diagnostics would tell the employees what has happened." – *IT Manager, Chemicals*
Existing data from machine operation underutilized	Current data could be used better in operating machines	"We know that we have a lot of data. We collect high amounts of data about the disturbances, about the reasons behind the disturbances. So, basically, we have all the data. However, when we have the database, how are we able to find something from there? The right things from the mass of data are the most important." – *Plant Manager, Pulp and Paper*
	Existing remote connections	"To some extent, we have remote connections in place. Sometimes, a supplier takes a remote connection, but it is not constant. If problems occur, we ask certain firms to take a look at them." – *Electricity and Automation Engineer, Chemicals*
	Data could be stored for a longer time for disturbance diagnostics	
	Lacking ways to intelligently explore data	
	Some applications of automated maintenance are available	
Fragmented data collection practices	Manual data collection	"Currently, data analysis is purely manual." – *Production Manager, Electrical Equipment*
	Employer data collection practices vary	"Our data analysis varies between employees and is done when a problem occurs, so it is not very comprehensive. It is more about finding the root causes of problems and maybe if we anticipate that problems might occur somewhere." – *Maintenance Manager, Chemicals*
	Data integration from sensors and machines lacking	

(continued)

Table 2 (continued)

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Non-predictive maintenance	Time-based maintenance	"If something has happened, like a machine has shut down, then we go through the automation system data to try to figure out what the problem is." – *Operations Manager, Marine*
	Data analyzed after something has occurred	"We use data very poorly. We have the weakness that data are only researched when a failure occurs. Only then do we research the causes but not beforehand. We should be doing this more, and we should have resources that somebody would research this more deeply." – *Electrical Maintenance Manager, Chemicals*
	Maintenance program poorly followed	

heavy machinery (see Table 2), the value realization constraints in heavy machinery companies (see Table 3), and predictability as the key IoT value driver (see Table 4). We also stated some managerial implications for firms utilizing or planning to utilize the IoT in heavy machineries.

Findings

First, we present our findings regarding the current situation with regard to data use in firms using heavy machinery. The second part presents our findings regarding data and IoT value realization constraints in heavy machinery. The third and final part presents our findings of key IoT value drivers from the viewpoint of middle managers.

Present State of Data Use in Value Creation in Heavy Machinery

Our study exposes four core issues regarding the *state of data use in heavy machinery*: (1) data abundance, (2) existing data from machine operations underutilized, (3) fragmented data collection practices, and (4) reactive and preventive maintenance. Our findings are summarized in Table 2.

The middle managers we interviewed throughout our study expressed that there is already an abundance of data existing at factories and units using heavy machinery. All of the case firms we studied used automation systems in their production processes. The interviewees expressed that they measure almost everything from the process, including flows, temperatures, pressures, rotations, and vibrations. In contrast to the state-of-the-art automation systems, the case firms mostly manually

Table 3 Value realization constraints in heavy machinery companies

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Organizational constraints	Organizational silos in factories and units	"Organization silos are one obstacle. We have quite limited areas of responsibility, and we do not look at the big picture much. The IoT and looking to the big picture is a big change compared to current operations. People have been looking at only their production line and not neighboring lines." – *Quality Manager, Electrical Equipment*
	Costs and paybacks for investments in the IoT hard to estimate (rationale unclear) Difficult to find time between production and maintenance Managers and workers lack excitement about developing data utilization and the IoT	"We do not have time to do data analysis. It is engineers' work, and I am ashamed that there is no regular search for variances to see when things are changing in production. It would not be anything groundbreaking, but it is simply something that we would need to do but are still not doing. It would be great if it were automatized… [automatized data analysis] should be in place so that we would not need to go through trends manually, and I see that this would yield high benefits if the analysis was automatized." – *Production Manager, Pulp and Paper*
Resource and capability constraints	Increased automation and reduction of heavy machine workers	"In troubleshooting, the more complicated the system is, the more it brings value to have an external expert that can connect remotely. In a sense, we have a limited ability to handle more complicated problems compared to the people who work day-to-day with similar matters and can fix the problem very quickly as long as they get the data. This has proven to be valuable." – *Chief Engineer, Marine*
	R&D and IT resource constraints	"Our maintenance organization is getting slimmer and slimmer and our production organization takes care of production more autonomously, but they do not think that much about the equipment condition….The slimmer our organizations are getting, the more we need external help." – *Electrical Maintenance Manager, Chemicals*
	Lacking data analysis capabilities lacking	"If we think about the whole IT function, all the experimentations have decreased, and so we do not test new ideas as much as before…Our equipment suppliers might do these activities more often, but in our organization, this is very little… We have been cutting costs for many years everywhere, so we cannot take risks and invest in something totally new to see if it works. This has clearly decreased." – *IT Manager, Factory B, Pulp and Paper*
	IT security challenges Constraints to engage external experts for analyzing machines (i.e., troubleshooting)	"Our main suppliers [suppliers 1 and 2] could send data packages to us about our equipment condition, and they could do data analysis and send suggestions based on their findings." – *Captain, Marine*

(continued)

Table 3 (continued)

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Sensemaking constraints regarding data use and the IoT	Managers feel that more data are not needed	"Current data could be used more. It would be useful that we would know how to use it better. It is very clear that it would help in developing different process states, speed and quality issues. Usually, the problem is not that we would not, have data but instead, how we could use the current data smarter." – *Unit Manager, Unit A, Electrical Equipment*
	Abstract investments are difficult to plan	"It is quite difficult to compare different factories because they are quite different. If the factories had similar production processes and products, then there might be some benefits. However, I see more internal benefits." – *Production Manager, Electrical Equipment*
	Difficult to compare factories Safety benefits from the IoT are unclear	

Table 4 Predictability as the key value driver from the IoT

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Production optimization	Production quality improvements	"Where we would have use of big data and automatic data collection would be especially when we see that the production line is making the best quality end products, and then we could save those data and parameters easily. The next time in production, we could control the production so that it would alert if operators would try to break the optimal quality parameters. For this kind of monitoring and control, we would pay anything." – *Production Manager, Electrical Equipment*
	Cost-efficiency improvements Production reliability improvements Available production improvements	"The future should be in advanced process control where data are analyzed, and optimization programs are developed based on that, so that any process can be controlled." – *Maintenance Manager, Chemicals*
Maintenance and recovery optimization	Capabilities for predictive maintenance	"We should develop predictability about when our production equipment is about to break down. It would be interesting to know beforehand…If we could prolong all equipment maintenance to stoppages without surprises it could be very valuable…. Predicting that equipment lasts until the next stoppage would be useful so that we would not need to fix it too early. If that information would be available two to three weeks beforehand, it would be good, as then we would not need to shut down production for separate stoppages." – *Maintenance Manager, Pulp and Paper*
	Speeding up production recovery Machine life cycle management	"Machines can be sometimes extremely difficult to fix and if something comes up quickly. It is very beneficial to know the machine and the symptoms beforehand. With this kind of predictability, it is possible to get acquainted with the machine's history, repair history and know how it has been functioning, what it includes and be able to procure needed spare parts beforehand." – *IT Manager, Factory A, Pulp and Paper*
Energy efficiency	Energy efficiency gains are high within and across factories and units (especially in energy-intensive sectors)	"There is a lot of potential in energy efficiency. In that area, we can benefit a lot from IoT systems, and then we could connect to different factories. This works definitely." – *Plant Manager, Pulp and Paper*
	Energy usage optimization	"We measure energy in many places already, but we do not use that information to control our production. I think it should control production and tell how much was consumed, making certain variety or comparing energy usage between shifts. There would be potential." – *Electrical Maintenance Manager, Chemicals*

(continued)

Table 4 (continued)

Second-order themes	First-order concepts	Exemplary quotes related to the theme
Safety improvements	Factory safety improvements	"In many cases, a reliable factory is also safe and cost-efficient when there is no constant need for repairs. Also, abnormal situations are the least safe for maintenance. In that sense, predictability and knowing equipment failures beforehand result in smaller disturbances and repairs in maintenance." – *Maintenance Manager, Chemicals*
	Predictability improves safety	"It could be summarized that fewer unexpected problems that need uncertain and quick fixes result in more predictability, so that the problems can be fixed in greater control, and this all leads to higher safety." – *Production Manager, Electrical Equipment*
	Advancing public image (safety and the IoT)	

conduct their data analyses. Therefore, the factories, units, and firms using heavy machinery have an abundance of data, but they are neither analyzed nor extensively used. As one production manager explained:

> Currently, data analysis is purely manual. – *Production Manager, Electrical Equipment*

Despite the abundance of data, the factories, units, and the corporation are not able to use those data in the ways that they would like. Existing data from machine operations are clearly underutilized. The corporations lack ways to intelligently explore the data. As one plant manager explained to us:

> We know that we have a lot of data. We collect high amounts of data about the disturbances and about the reasons behind the disturbances. So basically, we have all the data. However, when we have the database, how are we able to find something from there? The right things from the mass of data are the most important. – *Plant Manager, Pulp and Paper*

One reason for this is that data analysis is mainly decentralized to single factory lines and single heavy machines and dependent on employees' own motivations to perform the analyses.

Two of the case firms have established remote connections to the factories and units that allow centralized machine data analyses by their research units located at another location. For example, the product research unit of the pulp and paper company is able to remotely help the factories, even though the experts are scattered around Europe. This allows the company to pool together the data scattered around different factories and deploy centralized support to any site. In addition to intrafirm remote connections, interfirm remote connections are also possible to some extent. Both the chemical and pulp and paper companies we studied allow remote access by some machine suppliers to their production sites to provide technical support.

> To some extent, we have remote connections in place. Sometimes, a supplier takes a remote connection, but it is not constant. If problems occur, we ask certain firms to take a look at them. – *Electricity and Automation Engineer, Chemicals*

While there are already some remote connections, service and maintenance are very much grounded in reactive and time-based practices. While companies collect and send process data to databases for storage and later analysis, the data are seldom used. Proactive maintenance is currently limited to regular maintenance schedules based on time intervals instead of predictive maintenance and machinery conditions being continuously monitored and evaluated. The case firms are not using the available data to develop the service and maintenance process. Even though the interviewees identify the possibility to use the available data to recognize early symptoms of technical failures, the usage of the existing data is mainly triggered by an incident. As an operations manager in the marine company explained:

> If something has happened, like a machine has shut down, then we go through the automation system data to try to figure out what the problem is. – *Operations Manager, Marine*

To summarize, although many technical aspects of IoT (such as sensors, databases, and remote connections) have been implemented, most of the opportunities with the gathered data have yet to be fulfilled. More systematic and full-scale data integration from sensors and machines is lacking.

Value Realization Constraints in Heavy Machinery Companies

Next, we focus on the value realization constraints by companies using heavy machinery. We found three firm-level data-related value realization constraints: (1) organizational value realization constraints, (2) resources and capability value realization constraints, and (3) sensemaking value realization constraints. Our findings are summarized in Table 3.

Although the case firms have invested in the hardware to collect and store data, they have not changed the organization in a way that supports the analysis and use of these data. First, data gathering and analysis are organized within the production lines of factories and with single or few heavy machinery units rather than being collected and analyzed across many production lines and heavy machinery units. The collection and analysis of data are done in silos, and there is no single place to find the data nor ways to explore the data more collectively and systematically. As a quality manager explained to us:

> Organization silos are one obstacle. We have quite limited areas of responsibility, and we do not look at big picture much. The IoT and looking at the big picture are big changes compared to current operations. People have been looking only at their production line and not at neighboring lines. – *Quality Manager, Electrical Equipment*

Another organizational data and IoT value realization constraint that we found was that managers and workers lacked excitement about developing data utilization and the IoT. In part, it was explained to us that this is since the costs and paybacks of investments in the IoT are hard to estimate. Furthermore, there is simply a lack of time between production and maintenance to analyze or develop organizational practices within the single factories or units of heavy machinery.

Therefore, there is clearly a lack of both resources and capabilities to use the data and explore the value in the data. The managers explained that the current workforces at the case firms' production facilities are not equipped with the skills required to utilize the existing data. Furthermore, they are also not incentivized to acquire the needed skills. Finally, managers and workers are not provided with data analysis tools and software to make sense of the data. As an electric maintenance manager explained:

> We use data very poorly. We have the weakness that data are only researched when a failure occurs. Only then do we research the causes but not beforehand. We should be doing this more, and we should have resources so that somebody would research this more deeply. – *Electrical Maintenance Manager*, *Chemicals*

As such, adding more data may not be a solution before the case firms develop capabilities to apply the existing data and before new tools are in place to utilize new data.

> We already have too much information from the automation system to our operational employees. However, on the other hand, this information could be used better when disturbances occur so that the diagnostics would tell the employees what has happened. – *IT Manager*, *Chemicals*

Furthermore, the middle managers we interviewed revealed that the focus of top managers has been more on cutting costs than generating new growth avenues. This resulted in both physically limited resources and atmospheres that do not encourage experimentation. Data analysis is considered an additional task on top of daily routines. With limited resources for data analysis within the companies, factories, and units operating heavy machinery, the development of solutions to the current data and IoT implementation challenges have been increasingly moved toward external partners. As one manager we interviewed explained:

> Our maintenance organization is getting slimmer and slimmer, and production organization takes care of production more autonomously, but they do not think that much about the equipment condition […] The slimmer our organizations are getting, the more we need external help. – *Electrical Maintenance Manager, Chemicals*

Finally, our study also points out one central value realization constraint from the data and IoT for middle managers' constrained sensemaking of technological solutions and its value. The interviewed middle managers found it difficult to understand the IoT and digitalization. They were not aware of how they could improve the use of existing data, especially with the current resources. For example, a middle manager we interviewed had a hard time seeing the substantial benefits of knowledge sharing between factories.

> Maybe some special cases that do not occur often would be beneficial to know how they are handled in different factories or about how different processes are carried out in different factories. – *Maintenance Manager*, *Pulp and Paper*

To conclude, as of now, only a small proportion of the data is used in decision-making in operations and maintenance in firms using heavy machines. This finding is congruent with earlier studies about low data usage (Accenture 2015a; Manyika et al. 2015).

Predictability as the Key IoT Value Driver

Next, we move to our findings regarding how middle managers perceived the potential of the IoT to advance the development of value from heavy machinery data. Our study suggests four key value drivers from IoT in heavy machinery operation: (1) product optimization, (2) maintenance and recovery optimization, (3) energy efficiency, and (4) safety improvements. The four value drivers are all founded on advances that can be made with IoT with respect to predictability. Our findings on the key value drivers are summarized in Table 4.

We find that middle managers perceived *the potential to increase the predictability of production machinery and processes* as the key underlying value driver of the IoT. Predictability encompasses improved information on machine failure symptoms, relationships between the physical conditions and production, and production process lead times. The middle managers observed that increased predictability could create value in multiple ways, such as decreased down times through predictive maintenance, the further optimization of production processes through decreased wait times between production processes, increased energy efficiency, and improved safety.

> We should develop predictability about when our production equipment is about to break down. It would be interesting to know beforehand […] If we could prolong all equipment maintenance to stoppages without surprises, it could be very valuable […] Predicting that equipment lasts until the next stoppage would be useful so that we would not need to fix them too early. If that information would be available two to three weeks beforehand, it would be good, since then we would not need to shut down production for separate stoppages. – *Maintenance Manager*, *Pulp and Paper*

Predictive maintenance would decrease the number of disturbances and increase equipment reliability, factory availability, and output. The interviewees focused more on the potential to increase revenues rather than on cost savings. According to the middle managers, predictability could also enable further production optimization. The case firms have thousands of machines and components in their production facilities, and there is room to improve the understanding of their interrelationships. This would require both a better understanding of their equipment as a system and focused monitoring on the most important machines for the continuation of operations. Furthermore, a more systemic understanding of the production processes and the underlying environmental factors would then help to improve factory equipment life cycle management and would result in cost savings in investments.

> In addition to single components, it is important to understand machine systems and especially critical ones to be able to recover faster from disturbances. All the bottlenecks and all common systems are probably the places where this kind of monitoring comes most. – *Development Manager*, *Pulp and Paper*

Additionally, all of the focal firms acknowledged the importance of energy efficiency. There is significant potential for improvement. For example, production is currently not yet controlled using energy prices. However, the IoT was not unanimously seen as an answer to improved energy efficiency, even though many of the interviewees believed in this.

> There is a lot of potential in energy efficiency. In that area, we can benefit a lot from IoT systems, and then we could connect different factories. This works definitely. – *Plant Manager*, *Pulp and Paper*

The middle managers also observed potential to improve safety with better predictability. The interviewees stated that a reliable and predictable factory is also a safe factory. Maintenance work is not carried out in a rush, and operational employees face fewer surprises. Employees can be better prepared for their work in production and maintenance when they know the changes in environmental and machine conditions, which then affect their choice of tools and mind-set. Unprepared and ad hoc activities would then be reduced, which would also decrease the number of safety hazards. A decreased number of accidents would also result in an improved work environment, in fewer sick days, and finally in improved employee efficiency.

> It could be summarized that fewer unexpected problems that need uncertain and quick fixes result in more predictability, so that the problems can be fixed with greater control, and this all leads to higher safety. – *Production Manager*, *Electrical Equipment*

To conclude, collecting a vast amount of data is not enough to reap the IoT benefits described above. Knowledge sharing within and across production units and across organizational boundaries is needed. Systems for integrating and analyzing data must be in place.

Discussion

Our findings on the present state, constraints, and key value drivers of the IoT from the middle management perspective provide an "organizationally grounded" view of the IoT. While there has been much recent interest in the IoT, our case companies' middle managers possess a more conservative view on the IoT than those previously presented, coined *an evolutionary view on the IoT*. Our findings expose how middle management views IoT implementation as a gradual improvement to current operations rather than a revolution. As such, smart manufacturing, Industrie 4.0, and the IoT as revolutionary, disruptive, and a generator of novel business models is not how middle managers describe and perceive the IoT. Rather, our study points to predictability as being the most central value driver from the viewpoint of middle managers.

Managerial Implications

Our findings suggest that predictability as an underlying key value driver of IoT could be a better conceptualization for joining middle managers, top managers, outside experts, and firms in developing data and IoT systems in heavy machinery. Thus, in order to further implement IoT, top management should utilize the organizationally grounded view of middle managers. This organizationally grounded approach for IoT implementation would allow firms to harness the broader existing expertise from the factory and engage this expertise with the business unit, corporate level, and wider heavy machine IoT ecosystem strategy.

A second managerial implication derived from our findings is that organizations are in need of what we term *connected expertise*. With connected expertise, we mean a pooled group of experts that engage in real-time analysis work and decision-making with continuous information flows from multiple heavy machinery units.

Our results show that current knowledge and data are siloed within factories and units, far from the envisioned connected expertise. This present state should be the starting point for any IoT project. The distributed and disconnected knowledge and data need to be integrated to establish connections between data and experts. Such knowledge and data can be pooled in data and analysis hubs (also termed control or expert centers). Hubs must be able to be easily connected with suppliers. This will require the transformation of organizational practices and the disentanglement and removal of existing barriers between silos. Connected expertise could then gradually arise in hubs, where the best experts from various parts of the organization explore a pool of data in real time as a consorted effort. The role and skill set of the middle manager will need to be accordingly updated with data analytics understanding and adoption of exploratory skills in the same way as air traffic controllers.

The third managerial implication is that use of data and the IoT should be seen as a longer-term adaptation and organizational transformation project. Rather than portraying IoT strategies as system-level rapid implementation projects, the transformation of resources, capabilities, and sensemaking should be seen as programmatic long-term adaptation efforts. A digital modular "architectural view" on the transformation of the organization is needed to allow for the connecting of data from machines, sensors, devices, and humans. The longer-term adaptation program has another systemic-level implication. There are value drivers from the IoT that are clearly more easily implemented and have a high value. However, there are IoT value drivers that are much less clear with respect to payback time and overall value generation potential and are challenging to implement. Thus, systemic elements should also be carefully considered from the start, such as interfaces and platform governance structures, when planning data utilization and IoT project road maps. There is much required groundwork at factories and units using heavy machinery to have them engaged, committed, and informed in this endeavor. The chief digital officers (CDO), nominated recently in many firms, will play a central role in these adaptation and transformation programs as part of wider digital transformation efforts by the company top management teams to "encourage risk taking, foster innovation and develop collaborative work environments" (Kane et al. 2015: 9).

Research Implications

Our findings provide several avenues for future research on value drivers of IoT in the heavy machinery industry. As suppliers and customers become more closely connected through the development of the IoT (Burmeister et al. 2015), there is an increasing need to engage middle managers in developing connected expertise. How to advance such connected expertise, where middle managers' current expertise in heavy machinery is deployed, while their expertise in digital technologies and IoT is not yet at an advanced level, is still an open question. We see many opportunities for future research to study these questions. Based on our findings, we see that researchers could study how companies can refrain from too much top management leading data and IoT development projects and, instead, facilitate the active engagement of middle managers. For example, how could the IoT and data projects be organized, led, and scoped to incorporate the gap between expertise in the IoT and digital technologies and middle managers' expertise? Another question that would be important to study is how to incentivize middle managers to develop value from data and initiate innovation in IoT value creation. For instance, what roles and responsibilities could middle managers be given, and how could their expertise be actively updated and incorporated?

We also see much need for studies on how machinery firms across the value chain are exploring novel innovations and co-creation structures (Gronroos and Voima 2013) in IoT development and implementation with middle managers' active engagement. Insights from successes and failures in novel innovation and co-creation structures with active middle managers are important. This will allow us to take further stock of the opportunities from the IoT that otherwise are constrained by existing siloed organizational and technological structures that do not accommodate data access across machines, functions, and organizations.

Finally, as the IoT integrates supply chain networks where the information flows are easily transferred in networks (Burmeister et al. 2015; Koch et al. 2014), it requires new forms of interfaces and governance structures. While software developers have been critical in much of platform business development, the platforms in heavy machinery rely on the expertise in machines and their operation and management practices in which middle managers have played a critical role. An important question that requires further exploration relates to the novel governance structures and interfaces and how they can bridge the gap between middle managers and software experts.

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