APPLYING DESIGN THINKING FOR EXPLORING EMERGING TECHNOLOGIES AND CREATING MARKETS OF THE FUTURE

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ABSTRACT

Design Thinking (DT) is considered a must have approach for supporting innovation. Through its emphasis on empathy, user-centric design, and rapid prototyping and testing, DT offers a robust way for organizations to deal with complex and ill-defined problems. Yet, the success stories of DT have been mostly centered on the context of relatively established markets and technologies. In this research, we attempt to enrich our understanding of how DT is utilized for innovating in nascent markets characterized with high technological uncertainty and market ambiguity. By investigating Ericsson's exploration of the emerging Internet of Things, we propose five practices that enhance the application of DT for innovating with emergent technologies and creating markets of the future.

Keywords: Design thinking, Emerging technologies, Internet of Things, Nascent market

INTRODUCTION

To imagine the future and transform the present, Design Thinking (DT) asks 'what if?' (Kimbell, 2011) What if 911 operators could use fire alarms as a network of sensors to relay temperature and smoke data to fire fighters? What if a firm could track all their equipment in real time? To this we ask, what if DT was applied to strategic innovation challenges that require companies to simultaneously resolve complex technological challenges and make sense of yet inexistent markets and customers. DT has emerged as a general-purpose approach for sparking innovation, enabling public, private and non-governmental organizations to generate novel products and services (Brown, 2008). It has earned a reputation as being indispensable to innovation, thereby, organizations who fail to practice it are depriving themselves of an effective tool to innovate (Wylie, 2017). At its core, DT emphasizes themes of empathy to uncover the needs of end users, problem reformulation to produce novel insights, and rapid prototyping to test ideas and communicate new solutions to end users, clients, and innovation partners (Beckman & Barry, 2007; Brown, 2008). These principles enable DT to be applied to 'any area of human experience'(Buchanan, 1992: 16).

As an alternative to linear problem-solving approaches, DT is particularly well suited to addressing 'wicked problems', those that are ill-defined and characterized by complexity and uncertainty (Buchanan, 1992; Kolko, 2012). One context replete with ill-defined, uncertain, and complex problems is innovation in nascent markets (Anderson & Tushman, 1990). While DT is well equipped for dealing with such problems, certain characteristics of innovation in nascent markets indicate a need for an extended DT approach that fits the idiosyncrasies of nascent markets[1]. Notably, the fact that nascent market the market structure and users are unspecified seems to have important bearings on the application of DT. For example, while showing

[1] We defined nascent market as a period after a new technology emerges, but before standardization and mass commercialization take place. This market has been characterized with fleeting industry structure, unclear product definition, and unsettled commercial logic (Benner & Tripsas, 2012; Santos & Eisenhardt, 2009).

empathy to users is a central tenet of DT, however, in the absence of a specified user, it becomes extremely difficult to understand and address users' needs, values and emotions. Moreover, validating design ideas against existing profitability models is another key aspect of DT practice that becomes challenging in the context of nascent markets. When the underlying assumptions of existing value creation and capturing mechanisms lose their relevance and the alternative business models are yet to be identified, it becomes quite challenging for managers to validate a design idea. While DT literature is not short of success stories identifying well-designed and innovative product and services, such as new surgical instruments for physicians, easy to use features for cars as well as enhancement of existing financial and educational services (e.g. Brown, 2008; Brown & Martin, 2015; Sutton & Hoyt, 2016), there is room for further consideration of innovations for markets that do not exist yet. Beyond capturing instances of innovation, where the users are relatively easily identifiable, their needs are not particularly ambiguous, and the underlying technological uncertainties of proposed solutions are relatively quickly resolvable, practitioners and scholars need to know more about the puzzling situations that come with the simultaneous emergence of new markets, technologies, and business models. By doing so, it becomes possible to address the main strategic challenge that face many contemporary companies confronting discontinuous or even disruptive technological and market changes (Carlgren, Elmquist, & Rauth, 2016).

In this paper we argue DT and its foundational principles of emphatic user focus, iterative experimentation with multiple prototypes and creative solution and problem reframing are valuable to guide the strategic exploration of emergent technology in markets that are still forming. We use a case study that investigates Ericsson's strategic exploration of the emerging Internet of Things (IoT), and in doing so identify additional best practices that extend and complement the foundations of DT. These practices enable innovation managers to navigate multiple technological uncertainties and market ambiguities. As an enabling technology of the

4th Industrial Revolution (Industry 4.0), the IoT is characterized with high technological complexities as it requires recombination of multiple discrete technologies (e.g. RFID, sensor networks, cloud computing, Machine-to-machine) for enabling 'smart' devices to collect, analyze and increasingly make decisions with less reliance on human intervention (Gubbi, Buyya, Marusic, & Palaniswami, 2013; Richardson et al., 2017). As an emergent technology, the IoT is positioned to radically transform entire systems modifying existing markets and catalysing the creation of new ones (Schwab, 2015).

THE CHALLENGES OF APPLYING DT TO EMERGING TECHNOLOGIES IN NASCENT MARKETS

At its core, DT leverages a user or human centered design, utilizing empathy and ethnographic techniques to understand and explore the articulated needs of users (Beckman & Barry, 2007). Such insights provide the basis for problem reframing(s) and creative solution generation. Additionally, experimentation emboldens the use of prototyping to quickly and iteratively test and devise an optimal solution (Liedtka, 2015). According to Brown (2009), DT is successful when a proposed solution addresses three intersecting concerns: what is desirable from the users' perspective, what is technically feasible, and what is commercially viable for the organization. Yet, the technological uncertainties of emerging technologies, and market ambiguities characterizing innovation in the nascent IoT market present a question of how to apply DT in contexts where the needs of users, issues of technical feasibility, and commercial viability may be unknown. The position adopted in this paper, is in such cases it may be necessary to extend the core themes of DT to align with the contextual dynamics to bolster the utility of the approach in addressing complex innovation problems. The Figure 1 identifies sources of technological uncertainty and market ambiguity that require the central tenants of DT to be extended to help managers meet strategic innovation challenges.

- Insert Figure 1 about here -

Technological Uncertainties

New digital technologies are blurring the boundaries not only among existing products and industries but on a more fundamental level among the virtual, physical, and biological domains (Maynard, 2015). As such, the wider dynamic of convergence is shifting the focus of innovation from improving a single technology or process to leveraging and recombining multiple technologies to generate novel products and services. While emerging technologies may stoke excitement as new and previously unforeseen opportunities are presented, such advancements are also accompanied by high uncertainty regarding performance and interoperability, specifically concerning how different components of a technological system interact and function (Benner & Tripsas, 2012). The need to establish technical viability of emerging technologies highlights the value of rapid prototyping and experimentation advocated by DT, however, to build and test IoT solutions, for instance requires a degree of scale. To this end, the basic prototyping employed to develop a new tool may no longer be adequate when building a technological system that integrates different technologies and sub-systems. The uncertainty associated with emerging technologies is not just an issue of viability but the added complexity resulting from the contributions of different actors. In other words, emerging technological solutions may not be the outcome of a single producer as the requirements to generate a novel solution may breach the boundaries of multiple organizations (within firms and across them) (Gulati, Puranam, & Tushman, 2012). Thus, the concern is how to leverage DT in an open environment where innovation requires collaboration among multiple actors (Chesbrough, 2003). Collaboration here is not limited only to users, suppliers and competitors, but also requires deliberate engagement with universities, regulators, governments and different intermediates that may shape the development of an emergent technology (Perkmann & Walsh, 2007). Technological uncertainty implies the identification of potential collaborators is difficult and inducing cooperation in a collaborative endeavour could be problematic. Moreover, institutional environment with respect to regulation and government funding for an emerging technology may also be in its infancy. As such, this reinforces the potential breadth of collaboration but also draws attention to the need to expand the application of DT beyond prospective users. In doing so, responds to Kimbell's (2011) argument to shift DT beyond just designers and known users but attend to other known and unknown users as well as other stakeholders (Kimbell, 2011)

Market Ambiguities

Nascent markets are typically characterized by significant ambiguity, particularly with respect to the absence of a clear industry structure (Benner & Tripsas, 2012; Santos & Eisenhardt, 2009). This has important implications for how DT can be applied. The lack of defined industry structures means producers may not know which organizations represent customers or suppliers, or even competitors (Santos & Eisenhardt, 2009). Depending on the nascence of the market, the problem may not be limited to identifying who the customers or users are but that the customers may not yet exist. In some cases, a product is not developed with a particular user-group in mind or other in cases prospective users have no experience with the like products, consequently their needs are unformed and unarticulated but also subject change as their knowledge of the innovation may grow (Glynn & Navis, 2013). Ambiguity in nascent markets can also reflect the lack of convergence or shared understanding regarding what the product offerings are, their attributes and value (Kaplan & Tripsas, 2008). Subsequently, nascent markets sparked by disruptive technologies are sites of technological variation as firms advance different products with alternative configurations and functions (Grodal, Gotsopoulos, & Suarez, 2015). Ambiguity in the market results in a lack of consensus about the definitions of value creation (i.e. who does what) and value appropriation (i.e. who gets what) (Jacobides, Knudsen, & Augier, 2006). To this end, the absence of consensus about appropriate business models to structure transactions and appropriate value may constrain the ability of innovator firms to evaluate the viability of their innovation ideas.

The various market ambiguities mentioned above are particularly evident in context of the IoT where there is great diversity in potential application domains, presenting a range of user groups with heterogenous needs, and unestablished business models. Reflecting on this, draws attention to issue of having to apply DT when the users are either unknown or potentially too numerous to be strategically relevant. A consequent concern is how does DT help firms identify relevant users? Another concern is how to apply DT when the application domain is unknown, therefore presenting the challenge of what to develop and prototype. Having said this, the combination of technological uncertainties and market ambiguities present a wicked problem for firms entering the nascent IoT space, for which the core elements of DT can be beneficial. At the same time, however, the idiosyncrasies of the nascent IoT market require modifications to DT for it to be an effective innovation tool.

RESEARCH CONTEXT & METHOD

To understand how firms applied DT for emerging technologies in a nascent market, we studied the development process of IoT-related products and solutions at Ericsson. Ericsson is a global provider of telecommunications and networking equipment and services, and since its establishment in the 19th century has been a major player in driving innovations in the mobile networks industry, including 4G and 5G technologies. Advances in IoT technology have triggered the emergence of new categories of *smart* and *connected* products (e.g. smart home, connected cars, smart cities), which raise the need for connectivity solutions in various industries. The IoT opens new growth opportunities for telecommunication and network providers like Ericsson to go beyond connectivity services by expanding their offerings in data analytics, security services, and other industry-specific solutions.

Although IoT appears to be a new source of growth from the declining revenues of voice, messaging, and data services, however, realizing the opportunities of this nascent market presents several challenges for Ericsson's current business practices. First, the IoT industry is still in its infancy and the technology is evolving. There is no standardization of technology in place, and there is no dominant commercialization logic to follow. For a company who has benefited from standardization, this condition requires Ericsson to be able to deal with ambiguity and complex problems. Second, the wide application of IoT requires a set of new capabilities and no single company alone can fulfill them. Collaborations and partnerships with numerous actors across different industries and institutions become mandatory in the IoT landscape. This has important implications for business practices at Ericsson, which has been operating in an established industry with few competitors, and a specific customers base (i.e. mobile service providers). Finally, IoT involves more diverse connectivity requirements for different industrial applications. The need to have more diverse and customizable products/solutions might present challenges for Ericsson, which used to have a one-size-fits-all product development strategy. Acknowledging the associated challenges and the need to have a different approach for IoT, Ericsson created a dedicated unit (to explore opportunities in the IoT industry (called the IoT unit). In positioning the IoT unit as an innovation engine, Ericsson has sought to emphasize a customer-centered design and a fast-experimental approach aligned with the core principles of DT to develop products for the emerging IoT market. As such, this context provides an opportunity to explore how DT is practiced in a nascent market context.

Our empirical research involved multiple stages of data collection and data analysis. First, we conducted exploratory interviews with researchers and managers at Ericsson to understand the nature of their exploration activities towards IoT. This stage focused on the company's IoT strategy, the current products/solutions development initiatives, the related challenges in the firm's development efforts on IoT, and core DT principles applied by the development team. Second, we conducted an in-depth case study of three IoT development projects related to Smart Manufacturing, Connected Mining, and Smart Buildings. These three projects were chosen based on the maturity of the project development and its emphasize on the applications of DT principles at the development stage (see vignettes below for a detail explanation of the projects). In order to trace how DT is being practiced, we followed the development activities of the projects for about 12 months in the period between 2017 and 2018. Two of the authors spent between three and five days a week on the headquarter of Ericsson and conducted non-participant observations at 41 projects meeting. Field notes on the topic being discussed, the development challenges, and the design thinking practices were taken from each meeting. Additionally, we conducted 20 semi-structure interviews with the projects members which typically lasted between 30 and 60 minutes. The focused on the interviews was to understand the underlying logic of any strategic actions and design thinking principles implemented by the team. Finally, we also asked relevant managers to share with us strategy material and documentation relating to the technology and business development activities, such as business model, commercial engagements, and product development. We signed nondisclosure agreements with all parties to some of the sensitive strategy documents.

To analyze the data, we coded the data from field notes, interview transcripts, internal documents with a qualitative data analysis software by following Gioia's coding strategy (Gioia, Corley, & Hamilton, 2013). Since the data collection and analysis progressed in parallel, we were able to confirm our interpretations with the interviewees that allowed us to corroborate our findings. The coding process allowing us to identify a new set of design thinking principles and the associated activities and tools for developing solutions for IoT. Finally, we presented our findings to Ericsson senior managers in several workshops and informal group discussions to test the validity of our propositions.

Case 1: Smart Manufacturing

In mid-2017, a group of researchers and business developers started to wonder how to leverage Ericsson's strength in the wireless networks and the newly developed IoT technologies to tap into the Industry 4.0 trend. The team started to envision the future of manufacturing and what it may look like, and how wireless network and IoT technology could make a factory "smarter". Manufacturing companies, however, are a new type of a customer for Ericsson, who has predominantly worked with service-oriented telecoms. The concept of smart manufacturing is a loosely defined concept without a clear product definition and market needs. Given the limited domain knowledge and the immaturity of the technology, the project leader believed that the only way to develop products/solutions was by working closely with relevant actors in the manufacturing ecosystem (e.g. factory owner, equipment/machinery providers, and factory workers), and by utilizing a fast and iterative process of product development. The project team adopted guiding principles of being "customers obsessed" and "failing fast". At present, the team has successfully launched the smart manufacturing offerings with relatively shorter development time and well-received market feedback.

Case 2: Connected Mining

In 2016, Ericsson initiated a collaboration with a Swedish mining firm to explore the future possibilities of integrating advancements in communication technologies (i.e. IoT and 5G) into mining operations. To facilitate idea generation, prototyping and testing of proposed solutions for Connected Mining, Ericsson branded the initiative as a 'project-x'. Each project-x has a defined topic and life span (typically 6-8 weeks) in which a multidisciplinary team with complimentary knowledge on a topic (in this case members from Ericsson Research Strategic Design and Service Systems Research) employ 'design driven innovation' (i.e. a user driven approach) to improve existing goods, processes or services, or to develop ones that have not existed previously. The initiative resulted in a range of proposed solutions to increase productivity, improve safety, and enhance employee well-being in the mining industry. The project also illuminated solutions that could apply across different contexts like cities or factories.

Case 3: Smart Building

The project was started by a group of engineers who had an idea to install connected sensors at their workplace to know how many office desks and conference room are being used. After several trials and experiments, the initiatives gained interest from Ericsson senior managers to build commercial IoT solutions for workplaces and buildings. A development team consisted of engineers and business developers was formed with the focus on creating IoT solutions for the *Smart Building* market. The development team then started to collaborate with facility management companies and a startup company focusing on office virtualization software, since facility management industry was foreign for Ericsson. Moreover, the project leader initiated broad engagement activities with diverse stakeholders, including facility owners, tenants, visitors, emergency services, insurance companies, and property developers. From the continuous interaction with diverse users, the team has developed a range of smart building solutions for a more efficient workspace usage and reduced environmental footprint.

APPLYING DESIGN THINKING FOR INNOVATING IN EMERGING TECHNOLOGY AND NASCENT MARKET

This section describes the five practices identified during the investigation of the three IoT projects at Ericsson that extend the three fundamentals of design thinking (i.e. empathetic users focus, problem and solutions reframing, and iterative experimentations). The empirical evidence is organized under five sub-headings that introduce and explain each principle.

A. Domain selection

Building a deep empathetic understanding of the users is a key tenet of DT. Every innovation initiative should start from understanding users' needs and develop solutions based on those requirements. Nevertheless, in the context of emerging technologies and non-existing markets, it is not always evident who the users are. Therefore, before developing empathy with users, firms need to strategically search for an application domain and make a strategic decision regarding in which particular domain and user segment they should invest resources (e.g.

knowledge, financial, time). In addition, digital technologies like IoT are generative in nature (Yoo, Henfridsson, & Lyytinen, 2010), thereby presenting a multitude of potential application domains for various users in many industries. Managers can be swamped with a range of opportunities, spreading firms' resources too thin. One of Ericsson's senior managers underscores the importance of choosing and focusing on particular domains:

> "*IoT is evolving very fast and IoT is very wide thing, it can actually be almost everything. So, I think for us to be successful, it is super important to decide: OK these are areas that we can and must win and then expand from that"* (Head of IoT Unit, 2017).

Since not all opportunities are equal for all firms, when choosing an application domain firms should consider how attractive a market is and to what extent a firm's resources and capabilities can be aligned. The primary question is how firms select a new application domain given the volume of potential opportunities, and the ambiguity associated with the emergent domain.

Based on the cases within Ericsson, firms can select new application domains by responding to technological forecasts and major market trends. For instance, when deciding to focus on the manufacturing industry, the responsible unit in Ericsson utilized forecasts and analysts reports to identify where the largest investments in IoT will occur. Based on projections at the time, the manufacturing sector would significantly benefit from the application of new digital technologies and was deemed to be a major growth area. According to external analyst reports in Ericsson documentation indicated that the manufacturing industry spent over $150 billion on IoT related applications in 2017, and it is expected that expenditures will continue to grow. Furthermore, the company conducted a market research survey to determine the prospective users based on market potential and willingness to adopt IoT applications. As part of the domain selection, it is important to examine the trends with respect the evolution or trajectory of existing and emerging technologies. In the case of connected mining, current technologies may only provide for basic remote control and critical communications, however, expected advancements are anticipated to enable a range of new solutions like real time analytics, predictive maintenance, and remote inspection. Consequently, this emerging market has the potential to grow as nascent technologies like IoT and 5G mature.

Another approach to selecting an application domain is to look beyond existing segments and users using analogous thinking to identify new relevant areas and potential users. Analogous thinking is ideal for innovating in unfamiliar or new contexts as it encourages designers to draw upon past experiences or lessons and inspirations to apply ideas beyond existing users and applications (Gavetti, Levinthal, & Rivkin, 2005). For instance, in the case of smart buildings, Ericsson engineers had the idea to apply emerging cellular technologies to the fire alarm for a smart building solution. Drawing inspiration from an existing application in emergency notifications systems led Ericsson developers to envision a fire alarm capable of not only alerting individuals in the immediate vicinity but leveraging cellular networks to communicate directly to emergency operators and fire fighters, and to transmit real-time data (e.g. temperature or smoke density) to support an appropriate response.

Once a potential domain has been identified firms will likely need to address, which technological expertise is needed. The innovation team might not have all the required expertise within team; hence, the need to identify and recruit personnel with the right competencies. Eventually, a cross-disciplinary team should be formed to innovate with emerging technologies (Beckman & Barry, 2007). For instance, the development team responsible for smart manufacturing held a workshop with people from across the organization, such as research and strategy departments to map the required expertise and to identify existing gaps. From the workshop, came the realization they did not have industrial/manufacturing expertise within the team. The team then decided to recruit personnel from the supply chain department with expertise on production and manufacturing. In the end, a multidisciplinary team of 10 people with different expertise in IoT, manufacturing, product development, and business development was formed for the smart manufacturing project.

B. **Ecosystem-centric**

Innovations in digital technologies are also shifting the configuration of markets exemplified by the growth of platforms and ecosystem perspectives. As such, innovations are involving a greater number of interdependent actors beyond the traditional producer and end-user relationship (Adner & Kapoor, 2010). Given this, it may be insufficient to focus only on the end users, thus consideration should be given to other relevant stakeholders, and their possible contributions to an ecosystem. It is important to identify who they are or could be, and what value they may offer in developing a potential innovation. For instance, when designing an IoT enabled fire alarm for the smart building project, the team started by identifying relevant stakeholders beyond the end-customers who might also use and benefit from the solution. The team later identified and engaged with several user groups: fire fighters, 911 operators, and building managers to solicit their insights. In a similar context, when developing solutions for smart manufacturing, the team started by identifying users and stakeholders that may need to be involved in developing solutions. In addition, the team used a visualization software that can illustrate the relationships and value exchange among ecosystem actors and helped them in exploring different ecosystem possibilities. A sample ecosystem map is provided at Figure 2.

- Insert Figure 2 about here -

In addition to identifying what actors may play a role in an emerging ecosystem, it is necessary to understand how proposed solutions will address the needs of potential users. To gather insights regarding the mining industry, a context traditionally outside of Ericsson’s core business area, the design team conducted a two-day site visit of a mine in northern Sweden. Discussions with and observations of workers in the mine provided provisional findings informing a subsequent two-day ideation workshop. The ideation sessions sought to bridge the current and emergent technologies of Ericsson with the identified goals/challenges of the mining company (e.g. increasing mining productivity and improving safety and workforce wellbeing), as illustrated by the following statement:

> *"To explore how technologies can make the works in the mines better… we wanted to check the mine workers perspective. So, we visited the mine and we spoke to the mine workers and different persons in the company to really understand the context and what problems they have"* (Senior Researcher, 2017).

Both the examples of smart mining and buildings highlight the value and contributions of employing ethnographic techniques to acquire deeper insights into the needs of users but to also capture the requirements for emerging technologies.

Building on the insights generated from engaging with potential users and ecosystem actors, the next important aspect is to focus on the problems that are most important for the users. The development team might be faced with a large amount of identified needs and problems by different types of users. Therefore, the team needs to iteratively reframe the problem and solution in order to improve the quality of the problem formulation. The reframing activity aims to challenge the existing conception of a problem and to come up with a new way of seeing articulated problems. The case of smart manufacturing shows how a continuous and deep interaction with prospective users and ecosystem actors helped the team to see problems in a different light. For instance, the team saw that most factories used cables to connect equipment and machineries after several initial factory visits. Based on this observation, the team thought providing wireless connectivity can potentially free the production floor from unnecessary cables, thereby reducing tripping hazards in the factory. Accordingly, the focus of development was to replace the wired connection with wireless connection using cellular technology. However, after several workshops with multiple stakeholders including factory owners, the workers, and machinery supplier, their primary concerns were not to free up the factory floor to reduce work accidents but a larger question of having the necessary technology infrastructure in the factory. In other words, the issue was not ‘cutting the cables’ but building the network architecture to support emerging and future IoT applications (e.g. asset tracking and monitoring). Based on the insights, the team started to redefine the problem and started to focus on developing wireless connectivity solutions for IoT applications in a factory setting.

Finally, innovation teams can benefit from co-creation activities with ecosystem members, since the nature of emerging technologies and markets can be challenging for a firm to develop solutions on its own. For instance, the connected mining team collaborated with different employees (managers, geologists, workers) of a mining company to capture their needs and insights early in the innovation process during a series of ‘design workshops’. Furthermore, firms can leverage crowdsourcing as a mean to generate ideas. The smart manufacturing team, for example, organized a hackathon event for Ericsson’s researchers across the globe. The team posted several pressing challenges in the manufacturing industry based on engagement with potential users and asked participants to form a team and come up with solutions (in the form of software programs, hardware applications, or conceptual ideas). From this activity, the smart manufacturing team received numerous ideas for solutions that can be refined and developed further.

C. Portfolio of integrated solutions

Another important practice observed in the development process of IoT solutions at Ericsson is the creation of a portfolio of solutions. DT encourages solution generation through iterative experimentations and trials. The complexity and ambiguity of emerging technology and a nascent market would require designers to generate a set of multiple solutions, rather than a single one. The solutions should be “user-centric” and treated as a series of hypotheses to be tested through iterations. In some cases, a combination of elements from various solutions will be required to solve a complex problem. The case of connected mining shows how Ericsson used a range of Augmented Reality (AR) and Virtual Reality (VR) applications to propose a range of integrated solutions based on the articulated goals/challenges of their Swedish mining partner. For instance, to advance mine safety AR combined with positioning sensors on both automated and manner vehicles to reduce the stress of driving and optimize traffic flow in the mines. During emergencies workers could use AR devices to receive directions to the nearest exits or rescue chambers.

Emerging technology in new contexts also tends to generate heterogenous needs amongst prospective users. The heterogeneity of demand often results from different levels of willingness and capabilities to adopt the emerging technologies (Khanagha, Zadeh, Mihalache, & Volberda, 2018). As a result, designers might face different or even contrasting requirements from prospective users within a single market. For example, the smart manufacturing team encountered diverging requirements from potential users. One group of customers wanted to deploy the IoT applications using cloud computing technology, while another group of customers preferred the solutions to be installed on physical servers on their premises. Additionally, the team faced two different functional requirements in which one customer group put more emphasize on the low cost, low energy, and small data functionalities, while the other favored ultra-fast and lower latency functionalities. To deal with the different requirements, the team decided to develop two scenarios of solutions for each requirement, instead of trying to accommodate all requirements into a single solution. The development of multiple solutions for the different contexts and requirements helped Ericsson to address a broader array of users' needs, while at the same time increasing the adoption of the emerging technology contributing to the development of the nascent market.

Additionally, solution generation activities should be coupled with a business model development activity. In the context of a nascent industry where the commercial logic is unclear, it is often uncertain how firms would generate revenue from the solutions. Therefore, a business model is important to understand how a solution can be converted into users' value and market opportunity. It is essential to have a clear understanding on how the value creation and value capture activity would look like as well as value exchanges between ecosystem actors, given the complexity and ambiguity of a nascent market. This is illustrated by one of Ericsson's senior manager below:

> *"You can't create a business case, if you don't have something to create it around. If you only have technology, then you need to use design principles to find some value where you can form a business around and can look into the revenue models"* (Service Design Manager, 2018)

The advances in digital technologies will require firms to renew their existing business model and shift beyond traditional transaction-based pricing model to a more innovative pricing model, such as subscription-based and usage-based pricing models (Amit & Zott, 2012; Zott & Amit, 2010). In the smart manufacturing case, the team organized several "*Business Model Innovation*" workshops with manufacturers and a university to develop a business model for smart manufacturing solutions. In one workshop, the value exchange between ecosystem actors were identified as well as the value propositions and revenue stream model. One of the results from these *users-driven* business model innovation activities was a decision to implement *As-a-service* model, where users will be charged based on usage of the service rather than purchasing the products and services upfront. By constructing a business model along with solution generation activities, development teams can ensure the technical feasibility as well as the business viability of solutions.

The adoption of a new business model might require firms to develop new organizational capabilities. Firms might need to change the organizational structure, re-allocate resources, and develop new competencies to support the new business model (Khanagha, Volberda, & Oshri, 2014). Therefore, the innovation team should identify the organizational capabilities needed to deliver the proposed solutions including the corresponding business model, and plan whether to develop the capabilities internally or acquire them externally. For instance, adopting the *As-a-service* business model which focuses on selling services and functionalities is challenging for Ericsson because of the focus on developing hardware-selling capabilities for many years. To support a more service-oriented business model, Ericsson created a dedicated unit called "Digital Service Design". The unit was responsible to drive innovation in digital service and to develop overall service-capabilities of the organization.

D. Large-scale Prototype

Prototyping is an integral part of DT as it allows designers to rapidly test the ideas and improve them based on the users' feedback (Beckman & Barry, 2007). During the initial phase of idea testing, prototypes can be built with simple materials, such as paper, carton, or clay to create a rough physical representation of proposed solutions. Comparatively, for a solution that consists of a complex system like IoT, a large-scale prototype is needed in the latter stage of solution development. Large-scale prototypes bring a degree of scale comparable to real operating conditions, which is necessary to understand how the various elements interact and function in delivering the proposed solution. In this respect, the large-scale prototyping helps to address two interrelated challenges: one, the feasibility of emerging technological solutions (complexities of the interactions among involved systems), and two, the ambiguity concerning the value proposition of the nascent market. To demonstrate the technology and shape the perceptions of what a smart factory could be, Ericsson converted one their own factories into a smart one. The Ericsson 'smart factory,' as a large-scale prototype, showcases wireless connected solutions, and enables various IoT applications, including asset tracking, precise localization, and data analytics. A key aspect of the prototype is to demonstrate how different integrated solutions function at scale in an actual factory setting.

In addition to establishing the technological feasibility, the large-scale prototypes also provide a platform for rapid experimentation and on-going learning. The converted Ericsson factory providers designers with access to a site, where they can iteratively test and experiment with potential solutions as they receive feedback from users. This point is illustrated in the quotes below:

> *"We are creating playground for our researchers and developers to come here in a real factory environment to try out new technologies to see how they work…we can fast iterate just by drawing something up here then send it down to the workshop..."* (Head of Process Management, 2018)

> *"We are eating our own medicine, using our own technology to make a better offer for our customers"* (Industry Expert for Smart Manufacturing, 2018)

The development of a large-scale prototype also enables Ericsson to help clarify the meaning and value proposition of a nascent market. By using its own assets to address both the identified needs of prospective users and their own as a manufacture, Ericsson can build the business case for adopting smart factory solutions. To this end, Ericsson has been able to capture and show improvements in performance with respect to reductions in the cost of production and improvements in productivity. Similarly, to demonstrate the potential benefits of smart buildings, Ericsson has recently converted its headquarters into another large-scale prototype. The intention again is to highlight both the viability and benefits of the integrated solutions, and in doing so help to build the credibility of the nascent market for smart building solutions.

In both the cases of smart factory and smart buildings, the use of large-scale prototypes provides an opportunity for prospective users and relevant ecosystem stakeholders to come and experience the demonstration. This is important as the large-scale prototypes offer a focal point for Ericsson to engage users and stakeholders, permitting exchanges of feedback and attainment of additional insights catalysing further ideation, and experimentation.

E. Innovation Narratives

Given the unsettled nature of emerging technologies and nascent markets, designers might face difficulties in translating abstract ideas and communicating them to users and stakeholders. Aligned with DT's strong emphasis on visualization, we propose the use of innovation narratives alongside with visualization tools to capture and display abstract ideas. Innovation narratives play an important role in shaping the understanding of both emergent markets and technologies. Narratives and storytelling can help designers and users among others to understand, relate to and envision a proposed solution or future market. As such, narratives support the translation of ideas and foster linkages between concepts and material representations, which not only make abstract ideas seem more concrete but enable actors to make judgements of value (Garud & Giuliani, 2013).

In the examined contexts of Ericsson, innovation narratives were found to fulfill three functions: internal idea selling and road mapping, and external market shaping. Internal issue selling illuminates the reality that some opportunities presented by new markets and emerging technologies may reside outside of a firm's core business, subsequently, innovation narratives are crucial in framing the rationale for the domain selection, communicating the proposed value of a solution, and acquiring internal buy-in as well as resources to develop prototypes. Narratives can focus on a business case for exploring an opportunity rather than just communicating the capabilities of the technology or design. For instance, in the development of smart building solutions, engineers utilized simple PowerPoint presentation to communicate their story, and build sufficient acceptance of their idea from the organization internally. The statement below also highlights the role of narrative for issue selling:

> *"Basically, you need to build some kind of story or use case. So, we built this story in a couple of PowerPoint slides, where we put our vision, like how this fire alarm could be used, especially in relation to what is on the market today to improve public safety. We make this illustration of how this fire alarm could talk to the cellular networks, connect to authorities and the fire fighters directly in order to alert them of a fire... People were not*

too excited to begin with. But it started to grow on people and then we were accepted in the end. So, it took some storytelling to get people on board." (Senior Engineer, 2018).

In addition to, internal issue selling, narratives can act as an innovation road map providing orientations and focus for the future development of an emergent technology (inclusive of market trends). Innovation road maps can articulate and visualize a firm's strategic goals towards a nascent market connecting multiple time horizons with expected technological developments. For instance, both smart manufacturing and smart mining have developed respective innovation road maps that describe the evolution of enabling technologies (at present and in the future) and the corresponding solutions. For the design teams, the innovation road maps can serve two functions. The first, provides a sense giving tool to solicit an internal commitment from the organization, and second, show the users how the technological solutions will develop over time to inform their investment decisions. An example of an innovation road map of smart manufacturing case is provided below.

- Insert Figure 3 about here -

As suggested above, innovation narratives are important in selling issues and orienting the focus of designers and users, however, they also play a key role shaping external perceptions of value and understandings of emerging technologies and markets. The unsettled nature of both may present nascent technologies and markets as abstract or fuzzy, which can constrain adoption and promotion. For example, the concept of a *smart factory* is a loosely defined idea, subject to diverging interpretations regarding the features and functionality of a factory to be considered "smart". To shape users' perception, the smart manufacturing team developed a visual narrative which illustrated Ericsson's concept of a smart factory. As illustrated in Figure 3, the narrative represents how a day in the life of a smart factory will look from the perspective of different stakeholders.

- Insert Figure 4 about here -

The connected mining case provides an interesting example of leveraging VR for digital storytelling. Building on insights from mine employees, Ericsson designers developed a 3D virtual replica of the mine to display possible solutions to identified needs and challenges. Given the future orientation of the proposed solutions it was necessary for mine workers to both see and experience the benefits of connecting mines. The mixed reality mine allowed both Ericsson and its mining industry partner to co-create a story that made the concept and potential benefits of smart mines not only concrete but meaningful. As such, VR as a medium enabled the generation of powerful market shaping narratives that made the nascent technologies and markets more familiar.

> *"A virtual replica of the mine can enable an endless range of AR, MR and VR applications. (For example) through mixed reality seen with virtual reality goggles, customers are able to experience a scenario where two excavators deep underground meet face to face* (Internal Document, 2017).

DISCUSSION AND IMPLICATIONS

Both established and technology-driven companies are increasingly facing the strategic challenge of balancing innovation that supports and sustains the core business in the present with exploring the highly uncertain opportunities of the future (Tushman & O'Reilly, 1996). Exploration requires overcoming the hurdles of simultaneously resolving complex technological challenges, while making sense of the ambiguous and unarticulated needs of customers in the future. Technological uncertainties of commercializing emergent technologies are further compounded by the recognition that successful innovation requires collaborative participation of multiple companies (Chesbrough, 2003). The ambiguity of a nascent market is based on the inability of a focal company to clearly identify who is the most valuable customer, and the non-existence of business models to appropriate the value of an innovation (Santos & Eisenhardt, 2009).

By investigating the challenges of an established and technology-intensive company that is exploring the emergence of IoT, we attempted to enrich our understanding of the utility of DT for developing innovative solutions under conditions of high technological uncertainty and market ambiguity. Prior research adequately addresses the conditions under which DT can support innovation efforts focused on a) exploiting familiar markets and customers albeit with radical new technologies, and b) transforming technological advances close to the company's expertise into a new market for the firm. Our findings illuminate how DT can be applied to an overlooked, yet important context: when a company explores complex and emerging technologies that simultaneously require the creation of new markets. Our qualitative analysis resulted in five strategies that support the application of DT in such contexts. The Figure 4 summarizes our insights and connects core principle of DT with the five strategies that increase the utility of DT for exploring emergent technologies for the markets of the future.

- Insert Figure 5 about here -

Each of the five principles contain specific implications for the innovation management practices of firms. Selection of the most promising market domain requires from a focal company to develop systematic approaches for scanning technological and market trends. Such forward-looking intelligence enables a firm to identify the most promising candidate markets of the future and groups of users who would benefit most from the emerging technology. This forward-looking intelligence, therefore, requires a combination of entrepreneurial competency for sensing productive opportunities in the future and in-depth understanding of technological trends. Mapping cross-functional expertise across the focal company as well as from outside of the organization is crucial for developing organizational capabilities for selecting the most promising markets in the future. Techniques such as scenario planning that require managers to creatively employ analogical reasoning could help with identifying opportunities for the future.

Exploring a nascent market domain requires mapping an emergent ecosystem of interdependent actors that collectively shape the innovation (Adner, 2006). Innovation managers and designers need to look beyond end-user's needs and apply an ecosystem-centric approach that identifies and satisfies a diverse need of multiple stakeholders. Techniques such as crowdsourcing could be extremely useful to solicit ideas for distant domains (Afuah & Tucci, 2012). Moreover, strategic engagements with regulators, standard setting organizations and research councils should accompany collaboration with industrial actors. Designers should be encouraged to reframe their initial understanding of a problem/need through continuous engagement with multiple partners in order to identify the most important problem to be solved. Designers could also involve users and other ecosystem actors in co-creation activities to generate ideas and solutions. In this respect, users are treated as a source of innovation not only as a subject of testing (Bogers, Afuah, & Bastian, 2010).

The complex nature of products/solutions for a nascent market brought by the emerging digital technology would require innovation teams to develop a portfolio of solutions that involve a complex system consisting of multiple technological elements. Along with the technological solutions, innovation managers and designers should identify the value creation and value capture mechanisms of the proposed solution by searching for an alternative business model. A new business model is essential to ensure the business viability of the solution given the unsettled commercial logic of nascent markets (Chesbrough & Rosenbloom, 2002). The adoption of a new business model might require firms to shift from their conventional way of doing business; therefore, firms should be prepared to develop new organizational capabilities to support the business model.

While a rough and small-scale prototype is beneficial to test and display ideas in the early stage of the ideation process, designers might need to develop a large-scale prototype at the latter stage of the development process when developing solution for complex and emerging technologies. Large-scale prototypes that bring a degree of scale comparable to real operating conditions is necessary to demonstrate how the various elements interact and function together and to clarify the ambiguity regarding the value proposition of a particular solution involving emerging technologies. The large-scale prototype provides a *living-lab* for designers and users to co-create together and rapidly test a proposed in a live operational setting (Cohen, Almirall, & Chesbrough, 2016). Additionally, a large-scale prototype would enable innovation teams to shape users' perception of a nascent market by showcasing how an abstract concept (e.g. smart building or smart factory) would operate in reality.

The unsettled nature of emerging technologies and nascent markets would require designers to develop innovation narratives to communicate an abstract idea internally and to shape external perceptions of value and understandings of emerging technologies and markets. Innovation narratives in the form of visualizations and storytelling, would support innovation teams in translating ideas and fostering linkages between concepts and material representations, which not only make abstract ideas seem more concrete but enable users to make judgements on value (Garud & Giuliani, 2013). To complement the innovation narratives, designers could develop an innovation road map that provides orientations of the future development of a nascent market following the expected technological developments and the firms' strategic goals. The innovation road map could solicit internal commitment from the organization regarding the future development of products/solutions and inform prospective users of the development trajectory to make informed investment decisions.

Overall, the case of Ericsson shows the practices of DT for innovating in a nascent market by utilizing emerging technologies. While using a single case study was appropriate for understanding the nature of emerging technologies and nascent markets and their consequence to DT practices, a multiple case study setting would enhance our understanding regarding the drivers of success or failure on implementing DT in a nascent market. For instance, a recent study indicates that organizational culture influences the adoption of DT as an approach for innovation (Elsbach & Stigliani, 2018). A cross-case examination of firms with different organizational culture and different innovation strategies regarding the application of DT would be a fruitful avenue for future research.

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FIGURES

Figure 1: Technology Uncertainty, Market Ambiguities, and Design Thinking

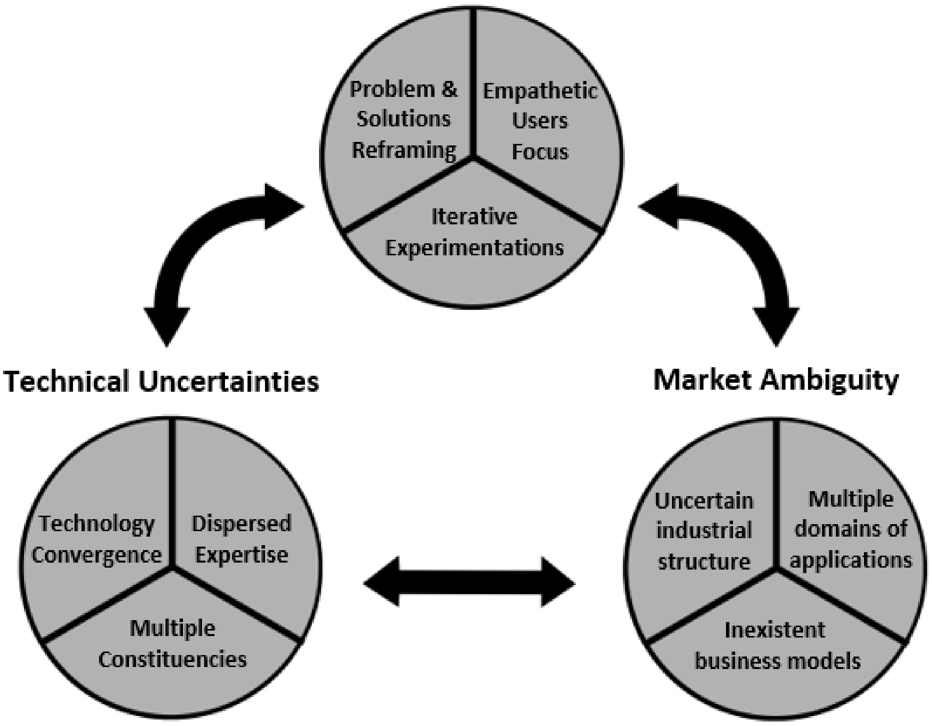


Figure 2: An illustration of Ecosystem Map for Smart Manufacturing Case

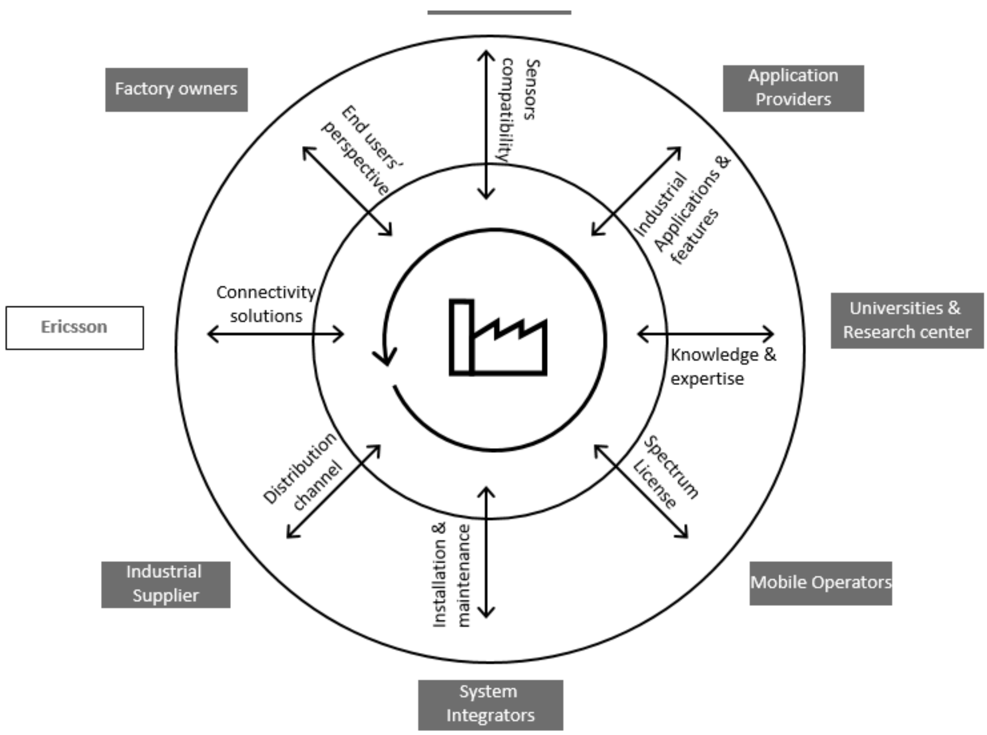
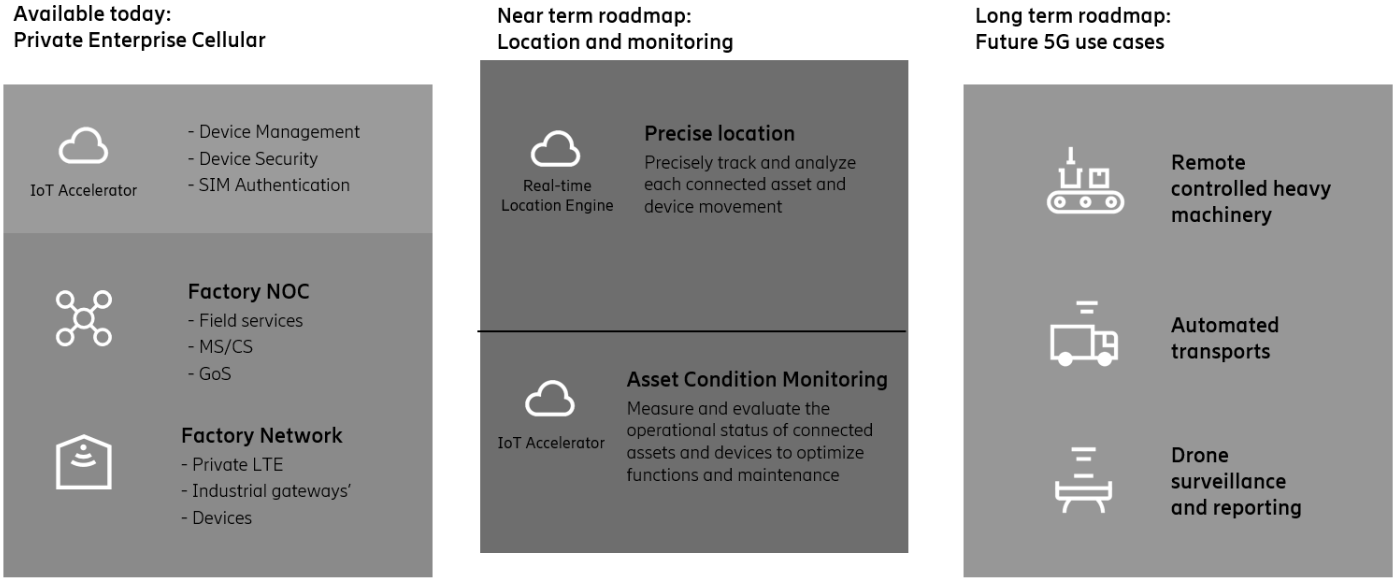
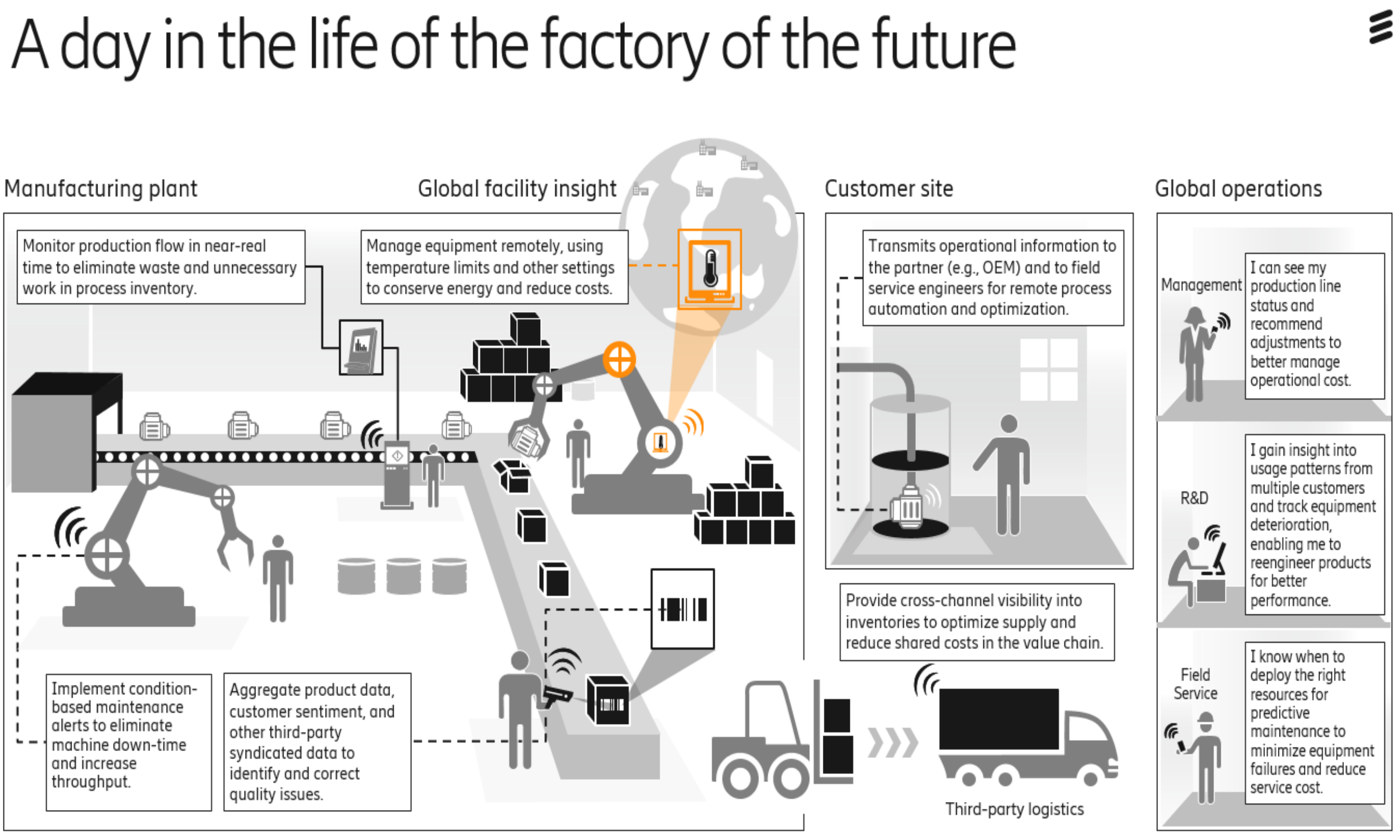


Figure 3: An Illustration of Innovation Roadmap in Smart Manufacturing Case



Source: Smart manufacturing commercial presentation (2018)

Figure 4: An Illustration of Visual Narratives for Smart Factory



Source: Ericsson's Smart manufacturing Promotional Slide, 2018

Figure 5: A Framework of Design Thinking for Innovating in a Nascent Market