Technology Innovation Management Review

March 2015

Innovation Tools and Techniques

Welcome to the March 2015 issue of the *Technology Innovation Management Review*. This month's editorial theme is Innovation Tools and Techniques. We welcome your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

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Overview

The *Technology Innovation Management Review* (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints – from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others – to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

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Editorial: Innovation Tools and Techniques

Chris McPhee, Editor-in-Chief

Brendan Galbraith and Nadia Noori, Guest Editors

From the Editor-in-Chief

Welcome to the March 2015 issue of the *Technology Innovation Management Review*. The editorial theme of this issue is **Innovation Tools and Techniques**, and I am pleased to welcome our guest editors: **Brendan Galbraith**, Senior Lecturer at Ulster University Business School in Belfast, Northern Ireland, and **Nadia Noori**, EU Researcher at BES La Salle – Roman Llull University in Barcelona, Spain. I am also grateful to **Bernhard Katzy**, Founder and Director of the Center for Technology and Innovation Management (CeTIM) in Munich, Germany, who provided the spark and inspiration for this issue.

This issue is based on articles selected and adapted from the 2014 International Conference on Engineering, Technology and Innovation (ICE) Conference, which took place last June in Bergamo, Italy. Dr. Galbraith is hosting the 2015 ICE Conference (www.ice-conference.org), which will be held from June 22–24 at Ulster University in Belfast, Northern Ireland.

This issue also includes a summary of a recent TIM Lecture by **Cheri McGuire**, Vice President of Global Government Affairs & Cybersecurity Policy at Symantec, who spoke on the topic of "The Expanding Cybersecurity Threat".

In our April issue, we will explore the theme of **Cyber-Resilience in Supply Chains**, and the guest editor will be **Omera Khan**, Professor of Operations Management at the Technical University of Denmark.

We hope you enjoy this issue of the TIM Review and will share your comments online. For future issues, we welcome your submissions of articles. Please contact us (timreview.ca/contact) with article topics and submissions, suggestions for future themes, and any other feedback.

Chris McPhee
Editor-in-Chief

From the Guest Editors

The innovation process, unlike many other management processes, is inherently risky and there is a myriad of routes for the few projects that finally graduate to commercial success. In many other management processes, for example, the recruitment and selection process for a new hire, it is a fairly predictable set of activities that will ultimately guide the process of appointing the most suitable and qualified candidate. Innovation, by its very definition, cannot be guided by a predictable set of activities, because it is a journey into the unknown, and there are many untested hypotheses about value propositions that may be related to the market, technology or society. Innovators need methods and tools to manage the innovation process, to test their assumptions, to truly understand the latent needs of their potential customers, and to develop products, services, or processes that calibrate with market reality.

Essentially, the innovator aims to progress their brilliant or simple concepts by minimizing risk at each stage of the process. Practitioners, whose job is to help or support innovative new projects in incubators or corporate spin-off facilities, have a fine balance to strike to ensure they are not providing artificial "life support" for unsustainable projects and instead focus on nurturing promising projects. The start-up model that they deploy to manage this risk and ultimately make the best use of their resources, must ensure that these projects can overcome "innovation constraints" – they need to be validated through a concise set of milestones in order to graduate to the next stage of the innovation process. As for the poor projects, well, as an investor would say, "poor projects must be drowned in shallow water".

With the advent of the digital economy and the clear emergence of numerous and large societal challenges in areas such as healthcare, energy efficiency, green technologies, sustainable transport, and the bioeconomy, there is a need for better tools and techniques for managing the inherent risk in the innovation process. In healthcare, for example, there are examples

Editorial: Innovation Tools and Techniques

Chris McPhee, Brendan Galbraith, and Nadia Noori

of quadruple-helix models such as living labs that are being deployed to balance user, technology, and market needs from the ideation right through to the launch of a new product or service (Galbraith et al., 2008). If we consider the rise in the popularity of the open innovation concept (Chesbrough, 2003), this approach to restructuring the management of innovation inside large corporations is a response to the failure of these wealthy corporations to effectively manage the risk in their internal innovation processes. If innovators can effectively reduce the risk in their innovation processes then, arguably, there has never been a better time to be involved in innovation. We are currently faced with numerous, large societal problems, which for innovators equates to big opportunities. Moreover, the availability of everyday, low-cost technologies and technology platforms helps to level the playing field for almost anyone to experiment with new applications and business models. The opportunities and available technologies are in abundance, but how do we combine that by translating the real latent needs of customers and cultivate a lucrative market?

As stated in a popular adage by an American industrialist: "It is about making the research machine work, and if you are doing that then the rest will follow. If you do it for the money, you do it wrong; if you do it right, the money will follow" (Galbraith et al., 2006). Although this quotation has been recited many times at industry events, it does raise important questions about innovation and how to do it right. What tools and techniques do *you* employ to make your research machine work? How do they allow *you* to manage the inherently risky innovation process?

The glue that binds the selected articles for this issue of the TIM Review is that each one makes its own contribution of tools and techniques for managing risk in the innovation process.

In the first article, **Carina Veeckman** and **Shenja van der Graaf** from iMinds-SMIT research group at the Vrije Universiteit Brussel in Belgium present a toolkit to optimize citizen involvement and bottom-up innovation in the public sector. Through a case study of a living lab framework implemented across four collaborative smart city initiatives in Europe, they show how more inclusive citizen involvement can be realized by providing users with tools that align with their specific capacities and skills. They also share lessons learned in applying a living lab approach to facilitate participation and co-creation, and to empower citizens.

Next, **Claude Baron**, **Philippe Esteban**, **Rui Xue**, and **Daniel Esteve** from the LAAS Laboratory of the CNRS (French National Center for Sciences and Research) in Toulouse, France, and **Michel Malbert**, entrepreneur and consultant, argue that the lack of integration between the systems engineering and project management domains poses a key risk for system and product development projects. Thus, to support the management of systems engineering projects, they propose the DECWAYS method and tool, which enables managers to bridge the domains and provide consistent follow-up and decisions in collaborative work and project steering.

Then, **Bernardo Nicoletti** from the Università di Tor Vergata in Rome, Italy, discusses how to improve innovation results and manage the uncertainties of innovation using the Lean and Digitize Innovation process, which integrates digitization into the Lean Six Sigma method while taking into account the possibilities of automation. Through its seven stages and 29 steps, the process helps organizations innovate from start to end: from the definition of the value for the customers up to the implementation of a prototype and engineering of the delivery processes.

Finally, **Ferran Giones** and **Francesc Miralles** from the La Salle Campus at Ramon Llull University in Barcelona, Spain, bring a signalling perspective to the process of technology entrepreneurship. By studying three new technology-based ventures, they explore how an entrepreneur's actions can be interpreted as strategic market, technology, and social capital signals designed to reduce uncertainty and unlock strong value propositions. Their key finding is that an entrepreneur's use of signals may positively influence opportunity exploration and exploitation and help them overcome their "newness", which manifests as the reluctance of potential customers to consider a new and untested product from a young venture.

We hope that you find value in the tools and techniques described in the articles we selected for this special issue and that they will contribute to your own efforts to research and manage risk in innovation.

Brendan Galbraith and Nadia Noori
Guest Editors

Editorial: Innovation Tools and Techniques

Chris McPhee, Brendan Galbraith, and Nadia Noori

About the Editors

Chris McPhee is Editor-in-Chief of the *Technology Innovation Management Review*. Chris holds an MASc degree in Technology Innovation Management from Carleton University in Ottawa and BScH and MSc degrees in Biology from Queen's University in Kingston. He has over 15 years of management, design, and content-development experience in Canada and Scotland, primarily in the science, health, and education sectors. As an advisor and editor, he helps entrepreneurs, executives, and researchers develop and express their ideas.

Brendan Galbraith is a Senior Lecturer at the Ulster University Business School in Northern Ireland. Brendan has led national and prestigious European research and innovation projects with a combined value of more than £4 million and his work has been presented in the European Commission, European Parliament, Northern Ireland Assembly and a wide range of national media outlets including the BBC. Brendan's research has appeared in *R&D Management, Technovation, Technology Analysis and Strategic Management,* and the *International Journal of Operations and Productions Management.* Brendan is the Book Reviews Editor for *Technology Analysis and Strategic Management* and has served on the European Network of Living Labs Leadership Portfolio Group.

Nadia Noori is a Researcher and PhD Candidate at the Fundación Privada Universidad Y Tecnología – FUNITEC La Salle Universitat Ramon Llull in Barcelona, Spain. She started her PhD in Crisis Management Networks in 2013 as part of the Marie Curie – ITN project. Her research work in crisis management is in the area of organizational collaboration and coordination complex networks. She holds BSc and MSc degrees in Computer and Control Engineering from Baghdad University, Iraq, and an MASc degree in Technology Innovation Management from Carleton University in Ottawa, Canada. Before commencing her PhD studies, Nadia was a Platforms and Product Manager at Coral CEA, a Canadian not-for-profit organization and open innovation network focused on building platform-based ecosystems.

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The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

> *“The tools bring the citizen to the forefront of democracy.”*
>
> A citizen of Manchester
> in the Citadel on the Move project

Lately, the concept of smart cities has been changing from a top-down and mostly technological-driven approach, towards a bottom-up process that facilitates participation and collaboration among city stakeholders. In this latter respect, the city is an ecosystem in which smart applications, open government data, and new modes of participation are fostering innovation. However, detailed analyses on how to manage bottom-up smart city initiatives, as well as descriptions of underlying challenges and barriers, are still scarce. Therefore, this article investigates four collaborative smart city initiatives in Europe to learn how cities can optimize citizen involvement in the context of public sector innovation. The analytical framework focuses on the different stakeholder roles in the ecosystem and the civic capacities to participate in the innovation process. The findings illustrate how more inclusive citizen involvement can be realized by providing different tools that align with the specific capacities and skills of the citizens. Furthermore, through specified workshop formats and peer learning, citizens lacking technical skills were also enabled to participate in the evolution of their cities, and to generate solutions from which both the city and everyday urban life can possibly benefit.

Introduction

The roll out of high-bandwidth connectivity and the growing adoption rate of mobile technologies such as smartphones and tablets are said to be transforming the public realm and the way we live and interact in urban areas. These and other digital technologies, such as wireless sensor networks and network-based applications, have begun to cover the city and have started to form the backbone of a large, intelligent infrastructure (Schaffers et al., 2012). Through these rapidly advancing technological capabilities, citizens are increasingly able to access real-time information about the city environment anytime, anywhere they want. However, at the same time, many cities are confronted with a wide range of challenges such as the environmental pollution, traffic jams, governance, etc. More specifically, city governments seem to struggle to meet the demands for improvement in public service delivery associated with the quality of urban life – while facing the prospect of ever-diminishing resources (Gudeman, 2008). In this regard, new technologies can help to map and understand information about the city dynamics and to deliver more effective services.

Furthermore, bottom-up processes are being increasingly considered for sensing the dynamics of cities based on the participation of citizens. Citizens are becoming actively encouraged to see the city as something they can collectively "tune", in a manner that it is efficient, interactive, adaptive, and flexible (Arup, 2010). By performing a multiple case study analysis of four collaborative smart city initiatives in Europe, namely Ghent (Belgium), Issy-les-Moulineaux (France), Manchester (UK), and Athens (Greece), we seek to yield insights into how bottom-up processes within smart city initiatives can be facilitated, with a particular focus on the role of the different stakeholders in the ecosystem and the civic capacities to participate.

To reach this objective, the article first discusses the smart city concept and the civic capacities to engage in the public domain, followed by an introduction of the living lab framework as a possible facilitator of bottom-up innovation. Next, the research design is presented with some additional information about the four cases. Finally, we discuss the interplay between the living lab methodology and the development of the toolkit, and how these were aligned with the capacities of the citizens.

The Smart City through Open Data and Mobile Apps

Over the past few years, many smart city projects and initiatives have popped up as a seeming answer to challenges that cities are facing (Pallagst et al., 2009). Challenges such as traffic jams, environmental pollution, etc., are demanding new and innovative ways to manage urban life and are pushing cities to invest in the necessary information and communication technology (ICT). In this context, the European Union (EU) funding programs such as Horizon 2020 (ec.europa.eu/programmes/horizon2020/) are an important driver to promote and support the development of smart cities throughout Europe. The smart city concept is relatively new and evolving, and many different definitions have been proposed. The mapping study of smart cities in the EU by the European Parliament showed that "Smart Cities come in many variants, sizes and types. Every city is unique, with its own historical development path, current characteristics and future dynamic. The cities which call themselves 'Smart', or are labelled as such by others, vary enormously" (European Parliament, 2014). The local development path, the interpretation of the concept, and place-specific characteristics can thus explain the various implementations of smart cities.

Among these different definitions and implementations, we see that, on the one hand, ICT plays a dominant role in becoming more intelligent, interconnected, and efficient (e.g., Hall et al., 2000), while on the other hand, a broader perspective with social and economic factors is incorporated in the definition of the smart city concept. In this article, we follow the definition of Caragliu and colleagues (2009) as it balances between economic and social demands, and links up to democratic processes. According to the authors, a city may be labelled smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government" (Caragliu et al., 2009).

Nowadays, the ICT layer underpinning the smart city concept relates to smart embedded devices ranging from smartphones to sensors, smart meters, and other instrumentation that sustain the intelligence of the city (Schaffers et al., 2011). Data coming from these sensors, or integrated networks, can provide citizens with real-time and location-based information. For example, sensors can monitor the air quality or detect patterns of movement of people in the city. These data, and information stemming from these datasets, can help governments in better understanding the city environment (e.g., improving urban planning) and in creating and delivering new effective services. Additionally, we see that more and more government entities are opening up their data, meaning "data produced or commissioned by government or government controlled bodies, which can be freely used, reused and redistributed by anyone" (Open Government Working Group, 2015). These data are made available at no cost to the public, so that, for example, (citizen) developers or startups can add relevance and value to the information and develop a service based on the data. In this respect, de Lange and de Waal (2013) consider cities as information-gathering systems in which data commons arise: "As these data are being aggregated, they may become a 'data commons': a new resource containing valuable information for urban designers". The availability of data and access to it, along with the skills of citizens to use the data in a meaningful way, are hereby two preconditions to establish a data commons (de Lange & de Waal, 2013).

In this context, urban competitions on open data, or hackathons, are increasingly being organized to stimulate the development of mobile applications. For example (Baccarne et al., 2014) illustrated that the goal of these hackathons is to stimulate both citizens and professionals to work with open government data, with the belief that it will result in more efficient and user-centric applications.

Smart city applications thus form a new digital layer of the city, in which citizens are not only invited to participate in the data collection (e.g., crowdsourced information about air quality), but also in the actual ideation and development process of the services. In this view, the services are not only thought to make the city smarter, but also to serve the mobile citizen in a better way (Hielkema & Hongisto, 2013).

The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

Participation, Citizen Involvement, and Civic Capacity

In the literature, some authors (e.g., Baccarne et al., 2014; Schaffers et al., 2011) are still rather hesitant about the value of ICT-enabled smart city solutions, while others clearly express their beneficial use (e.g., European Parliament, 2014; Hancke et al., 2012). According to the latter view, the use of ICT makes a city a "smart" city, because it improves the efficiency and effectiveness of the city processes, activities, and services. Despite these clear-cut opportunities, there is also the belief that, without engaging citizens about the role and impact of technology in their cities, the smart city vision will fail (FutureEverything, 2013). If cities want to reinvent themselves, solely pushing out highly technical solutions will not work, because new forms of digital divide can be created. Instead, a good balance between bottom-up processes (i.e., including the voices of citizens), and the technology push is desirable (Pallot et al., 2011). The mapping study of smart cities by the European Parliament (as referred to earlier) showed that one of the success factors for smart cities is "people", or the involvement of citizens in the creation and realization of the smart city vision (European Parliament, 2014). This form of participation shifts the role of the citizen from a mere passive subject into an engaged actor (Schaffers et al., 2012) and promotes the view of a "participatory governance", or as it is also called, "empowered participatory governance" (Abers et al., 2003). This democratic reform is called participatory because it relies "upon the commitment and capacities of ordinary people to make sensible decisions through reasoned deliberation" and it is empowered because it attempts to tie "action to discussion" (Abers et al., 2003).

However, meaningful participation will largely depend on the specific capacities and skills of the citizens (Wagemans, 2002). In this regard, Saegert (2004) speaks of civic capacities or "the ability to participate in public life with the result of more democratic governance at various scales". Moreover, Stembert and Mulder (2013) speak of different "participation parameters" to facilitate participation and co-creation between citizens and local governments. In their study, they focused on three parameters to investigate citizen participation in the public domain: ability, motivation, and satisfaction. The first parameter, ability, stresses the importance of guiding and supporting the users in a positive and obstructive way. Not everyone has the ability to easily express themselves or to imagine a proposed solution. Therefore, the authors' advice is to communicate in a "common language". For example, generative tools reveal a "new" language that is predominantly visual and they make use of a large set of components that together form "creative toolkits" that people can use to express their thoughts, feelings, and ideas (Sanders, 2000). These toolkits help to bridge the gap between developers and users. Besides providing the right tools and techniques, the users' motivation is another crucial parameter. Malone and colleagues (as cited in Stembert & Mulder, 2013) relate motivation to the goal users pursue: "money, love, and glory". However, public governments cannot reward participants with money generated by taxes and would be better off triggering citizens with "the motivator of love or glory in the form of creativity" (Leadbeater, 2006). Last, satisfaction refers to how the participation process is perceived as satisfying by the user.

These different parameters should thus be taken into account when seeking citizen involvement in the public domain. Furthermore, participation will always lead to some unintended consequences; there will be always some citizens that will be included, while others will be excluded (Turnhout et al., 2010).

The City as Living Laboratory: An Ecosystem to Foster Innovation

One way to organize bottom-up processes within smart city initiatives is by applying the living lab approach. Living labs can be regarded as "physical regions or virtual realities where stakeholders form public–private–people partnerships (4Ps) of firms, public agencies, universities, institutes, and users, all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts" (Westerlund & Leminen, 2011). The living lab concept appeared in academic discussion in the 1990s, but really took off in 2006 when the European Commission initiated projects to advance, coordinate, and promote a common European innovation system (Dutilleul et al., 2011). According to (Pallot et al., 2011), living labs are a good way to bridge the gap between technology push (i.e., solution developers) and application pull (i.e., user communities), because they bring the necessary combination of digital skills, creativity, and innovation methods together. Coenen and colleagues (2014) describe living labs following a "meet in the middle philosophy", an approach "for involving both the voice of citizens and local grassroots organizations to represent the bottom-up perspective and the voice of government and companies to represent the top-down view". Schaffers and colleagues

(2012) take one step further, stating that "cities are becoming a living lab itself, a playground of innovation and transformation", exemplified by the emerging ways of collecting and using urban data. Living labs can thus be regarded as an effective means to facilitate bottom-up processes within smart city initiatives, as they promote multi-stakeholder collaboration and consider users as innovators (von Hippel, 2005).

Living labs can have different thematic focuses and interests, such as focusing on innovation in health, media, smart grids, etc. In this article, we focus on urban living labs that specifically involve citizens in city development to make urban areas better suited to their needs (Juujärvi & Pesso, 2013). Obviously, the goal of urban living labs differs fundamentally from more ICT-oriented living labs, which tend to be rooted in commercial contexts; here, the generated public value will be more of concern than the economic value (Baptista, 2005).

Regarding the key participants and their roles, Juujärvi and Pesso (2013) found that the role of citizens in urban living labs is more comprehensive than in other types of living labs. They discovered that citizens can have multiple roles in urban living labs, ranging from a mere informant to tester as well as contributor and co-creator in the development process. Furthermore, the motivation to participate can also be different, because citizens can have a natural motivation to participate in shaping their environment through a "sense of place", "a sense of being at home in a town or a city" (Horelli, 2013). Last, the role of the city can be described here as the "enabler" or "mediator" in the ecosystem, bringing everyone to work together effectively (Ratti & Townsend, 2011).

Table 1 provides more information about the different actor roles in living labs (Leminen & Westerlund, 2012) and specifies the role for each stakeholder in urban living labs (Juujärvi & Pesso, 2013).

Research Approach

As part of the Citadel on the Move project (Box 1), this research was conducted by the iMinds-SMIT research organization (iminds.be/en) at the Vrije Universiteit Brussel in Belgium. The pilot project initially focused on a network of four smart city initiatives in Ghent (Belgium), Issy-les-Moulineaux (France), Manchester (UK), and Athens (Greece), where citizens were engaged to participate in the design of a toolkit to build mobile applications. At the same time, the four cities were opening up their data and transforming it into a publicly usable format. Citizens were invited to provide suggestions for new datasets or to convert the dataset by themselves.

Table 1. Actor roles in urban living labs (Juujärvi & Pesso, 2013; Leminen & Westerlund, 2012)

Common Actor Roles in Living Labs	Actor Roles in Urban Living Labs
Enabler: Organization that provide supportive technology, virtual or physical space, and other necessary resource for use by participants	*City representatives as enablers*: Create a vision, allocate resources, provide strategic leadership, and promote networking
Utilizer: Seeks efficiency gains and new knowledge, and wants to learn new practices to boost their innovation processes	*Firms and local service providers as utilizers*: Create suitable products and services, set small-scale objectives, and produce place-based knowledge
Provider: Public and private company or organization that provides the network with their product portfolio	*Educational institutions as providers*: Engage students as innovators, provide innovative R&D methods, and augment knowledge systematically
User: Potential customer of products and services from a provider or other actor	*Residents as users*: Participate in experiments, empower citizens through co-creation, and produce place-based user experience

The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

In this article, a multiple case study analysis of the four smart city initiatives is described. In the analysis, we focus on the following levels: i) the actor roles in the ecosystem and ii) the required civic participation capacities. These specific dimensions were chosen to provide an overview of the different stakeholders, to analyze the role they play, and to reveal how participation and collaboration is set up between the stakeholders in order to involve citizens.

In these different cases, Ghent and Issy-les-Moulineaux mainly focused on the delivery of better services within the tourism domain, whereas Athens and Manchester sought new services within the transportation domain to enable citizens to overcome health challenges and adopt more active lifestyles. In the latter two cities, sensor networks to measure air quality were also installed. By tapping into the innovation potential of citizens and by facilitating collaboration, these cities were interested in gaining better insights into citizens' needs and establishing a better communication with the citizen.

In early facilitated workshops, five main themes were identified from the discussions: i) environmental information, ii) parking in the city, iii) events in the city, iv) points of interest in the city, and v) crowdsourced information. Based on these themes, so-called mobile "templates" were created that citizen (developers) could use to quick-start the mobile application development process. The source code of the templates, together with guides, were made available on the project platform and GitHub (github.com/citadel-eu).

For our analysis, we used the user feedback collected from the living lab experiments of the four cases. These experiments were set up in an iterative and gradual approach, which aligned with the maturity of the mobile application development toolkit. In total, four iterative testing cycles were set up involving self-reporting methodologies (e.g., diaries), participatory methodologies (e.g., design charettes), and observational methodologies (e.g., participant observation in the city). By deploying this multi-methodological approach, feedback about various aspects of the toolkit was collected from the early stages of the project until the eventual self-governance of the toolkit. The chosen methodological approach was designed to test, evaluate, and co-create the toolkit with the citizens. These findings were used to investigate how bottom-up processes can be set up between the city and its citizens, and how hurdles can be tackled concerning the civic capacities of the participants.

Box 1. The Citadel on the Move project
(citadelonthemove.eu)

The Citadel on the Move project ran from 2012 to the beginning of 2015, with the objective of uniting local governments, living lab practitioners, ICT specialists, and citizens to harness the power of open data and user-driven innovation to develop mobile applications that can be easily shared across Europe. The project helped local governments to open up and share their data through a common architecture and usage of standards, and it helped citizens to take part in the application development process through different provided tools and workshops. By the end of the project, Citadel had helped more than 120 cities across Europe to open up their data and create over 600 basic applications.

The project was funded by the European Commission's Information and Communication Technologies Policy Support Programme (CIP-ICT-PSP.2011.5.1).

Findings

In this section, we first provide an overview of the different stakeholders in the innovation ecosystem, together with a role description. Next, the user feedback of the four cases is discussed along the different living lab testing cycles to formulate conclusions on how citizen involvement can be optimized.

Actor roles in the innovation ecosystem
According to the typology of Leminen and Westerlund (2012), we identify the following roles in the ecosystem: the city as enabler, the citizens as users, and the research organization as provider. The role of utilizers is not present within this ecosystem, because the scope of the initiative is more oriented towards generating public value. Figure 1 illustrates the different stakeholders and exemplifies the role they play within this particular ecosystem.

The four local governments play the role of enabler in this ecosystem as they set out the smart city objectives, provide the necessary resources, and bring the different stakeholders of the living lab network together. In all cases, the city promoted the networking among citizens, the developer community, students, small and medium-sized enterprises, etc. to increase awareness about open data and to enable cooperation among the

The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

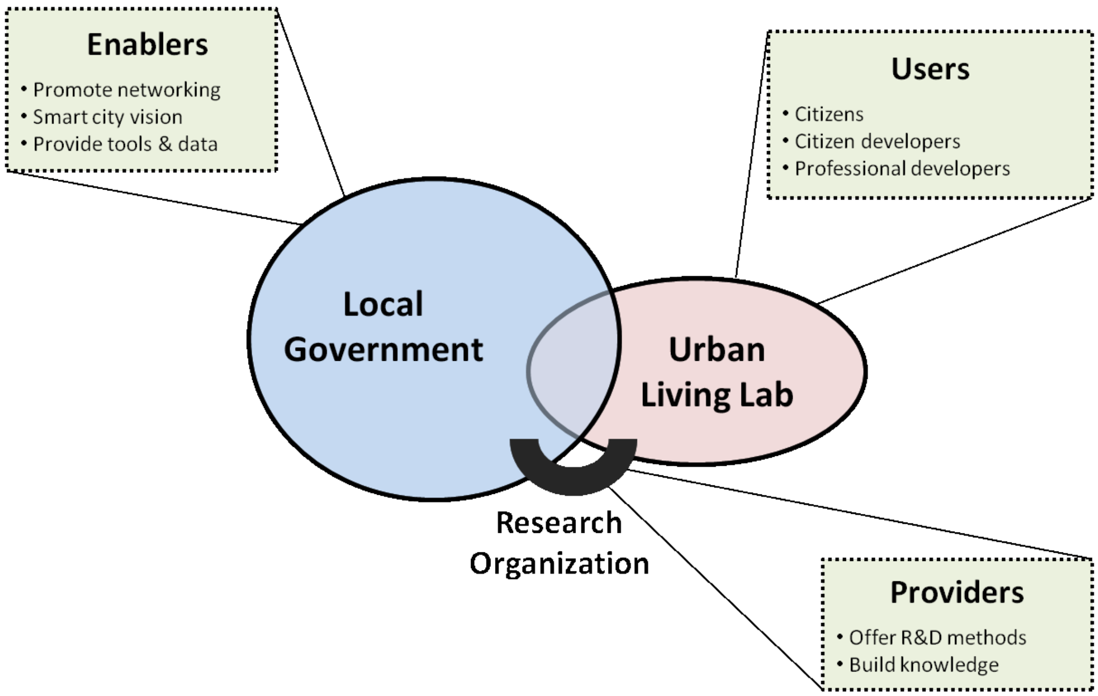

Figure 1. Actor roles in the innovation ecosystem

different stakeholders. During the living lab experiments, these stakeholders were brought together to both brainstorm and build around new ideas for applications with help from the provided toolkit.

A research organization (iMinds) was also involved in the ecosystem to provide innovative research and development methodologies. The organization had previous experience in the design and implementation of user-driven methods in living labs, and could thus accumulate knowledge over the long term. In this instance, the research organization did not have direct contact with the living lab participants, because such interaction would have a negative impact on the community building and citizen–government relationship. Instead, the research organization provided diverse protocols and guidelines to the cities on how to set up the living lab experiments. Afterwards, both the city and the research organization collaboratively assessed the results.

The last role is that of users, who were invited to provide feedback and participate in the co-creation processes. In this ecosystem, users were defined as citizens, (citizen) developers, and professional developers who were interested in using and creating innovative applications in the domain of tourism and transport. These different groups were segmented into different categories based on their level of skills and technical knowledge: none, limited, or high. The following sections show the importance of categorizing users based on skill level.

Testing, evaluating, and co-creating mobile (template) applications

In this section, the results are presented from the early user requirements workshops until the last iteration cycle of the mobile application templates. The findings show how cities organized the bottom-up processes and how civic involvement was accomplished.

In the summer of 2012, a first workshop was organized in each city to gather preliminary thoughts and expectations about how the creation of applications in the transportation and tourism domains could be facilitated. Various stakeholders were invited to these workshops to discuss new ideas based on some predefined paper mock-ups. These mock-ups described some basic application features, and mostly served to define the first user requirements.

In the next phase, the user requirements were taken into account to develop a first version of the application templates. Based on the stakeholder feedback, five mobile application templates were created, focusing on the following aspects: i) environmental information, ii) parking in the city, iii) events in the city, iv) points of interest in the city, and v) crowdsourced information. These templates were working mobile web applications based on HTML5 and PHP. JavaScript and JSON were also used to enhance the user experience and allow the communication with the application's back-end and data respectively. By providing these templates, the cities facilitate mobile application development, as anyone is able to download the source code from the platform. This way, citizens are able to personalize the application templates in order to meet their needs. For example, citizens are able to combine multiple templates, add or remove features and datasets, etc. Figure 2 shows a first version of the templates.

Through these standard templates, cities are providing an easy way for citizens to start creating their own public services, and it makes the development processes less time-consuming and more cost-effective. Furthermore, when citizens can easily access open data, the innovative potential of citizens becomes stimulated as citizens themselves can determine the mobile applications they want and need.

To gather user feedback and iterate the development, the applications templates were launched into the living labs networks of the four cities. In total, four iteration cycles took place in order to optimize the use of the templates.

In the first testing cycles, the cities agreed to only recruit "citizen developers", because these are the citizens who have some development skills as well as innovative ideas for new applications. In total, 25 citizen developers were carefully selected and tested the first version of the application templates. Feedback was collected from interviews, focus groups, and journals. This latter method could foster the self-reporting of citizen developers about the experiences and activities with the toolkits. Also, logging provided substantial information about the number of downloads, error information, etc.

After two testing cycles, the results showed that about half of the citizen developers had been intensively adapting the templates over a period of one or two days. The parking application and the crowd-sourcing template were perceived as most interesting, whereas the urban planning template was perceived as rather useless due to a lack of data. In general, the citizen developers found the application templates easy accessible. Because the templates had been developed using cross-browser HTML5 technology, there were no problems in using these templates on different types of mobile devices or operating systems. The user interface was rather well received and many suggestions were made to improve it.

Despite this positive feedback, none of the citizen developers actually started developing their own application, even after many technical difficulties were resolved after the first iteration. Furthermore, it became clear that the feedback differed depended on the skill level of the citizen developers. Some citizen developers perceived the download and installation pro-

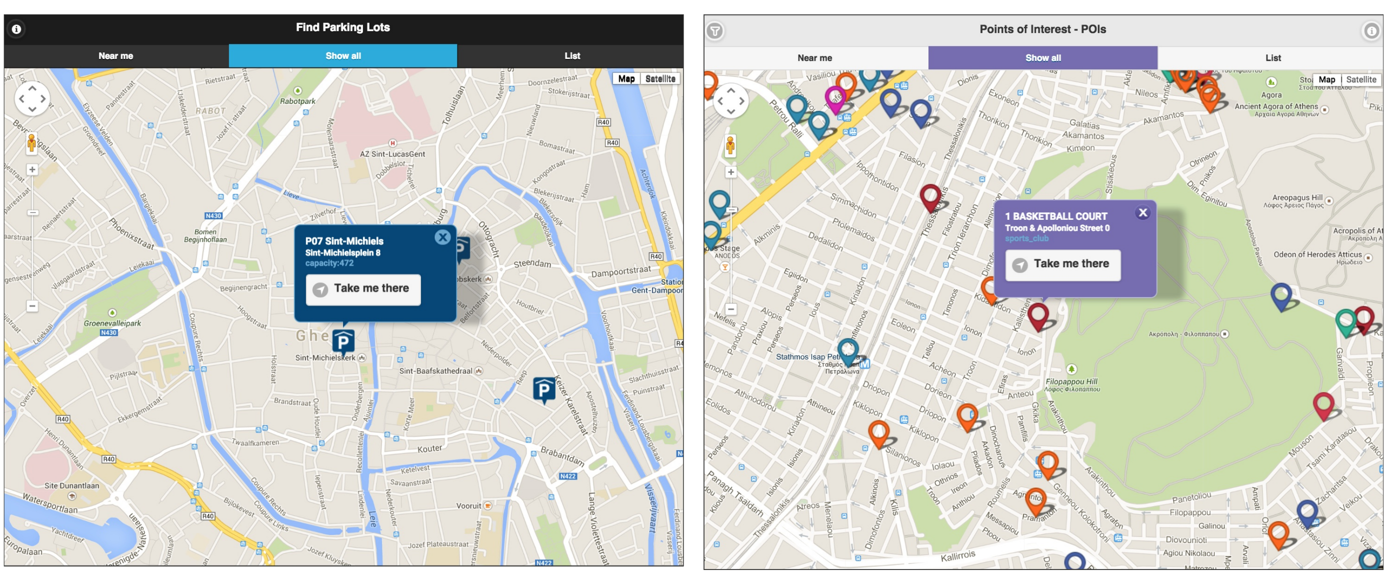

Figure 2. Screenshots of the parking and points-of-interest application templates

cesses as rather easy: *"I found and downloaded the app files fairly easily and had to make some changes to the config file, which I am used to doing"* (Manchester, December 2012). On the other hand, it seemed that some citizen developers were not familiar with these processes and stopped using the templates after downloading them: *"We should have something very basic, like for example, the framework of Wordpress, where you find some boxes to fill in – some drag-and-drop elements. This is clearly what I expected to see, not some coding lines"* (Issy-les-Moulineaux, December 2012).

In practice, less experienced citizen developers did not succeed in installing the templates, even with the help of others or when consulting the documentation. Instead, they evaluated the templates through the online demo website and stopped using the templates. In contrast, more experienced citizen developers were able to install and customize the templates. Based on this feedback, the cities and the research organization decided to implement a different approach based on the skill levels of the users.

After gathering feedback and iterating two testing cycles, none of the recruited citizen developers had created their own application. To increase usage and improve participation (regardless of skill level), additional tools were developed. The application templates would still remain available to the more skilled citizen developers and professional developers, however, a new tool, called the "App Generator Tool" (Figure 3) was made available to ordinary users. With this tool, citizens with limited-to-no technical knowledge could participate more easily in the application development processes. This way, cities guarantee that every citizen, including those lacking specific capacities, is able to become involved and be heard.

The role of the App Generator tool is to allow users to combine various datasets of a city and build an application online without having to write a single line of code. In order to generate a new application, users simply need to fill in a form. Several fields should be filled in, for example, to select a city and (one or more) dataset(s), to define the theme colour and fill in a title for the application. When the application is created, a unique identification number is assigned, and the application can also be shared with others.

Besides creating a more accessible tool, a separate evaluation track based on the level of skills was set up by the research organization. This step was necessary because, in the upcoming testing cycles, not only citizen developers were involved, but also a larger number of ordinary citizens. Therefore, separate surveys were programmed: one evaluating the application templates through the demo website for non-technical participants and one survey that guided the more experi-

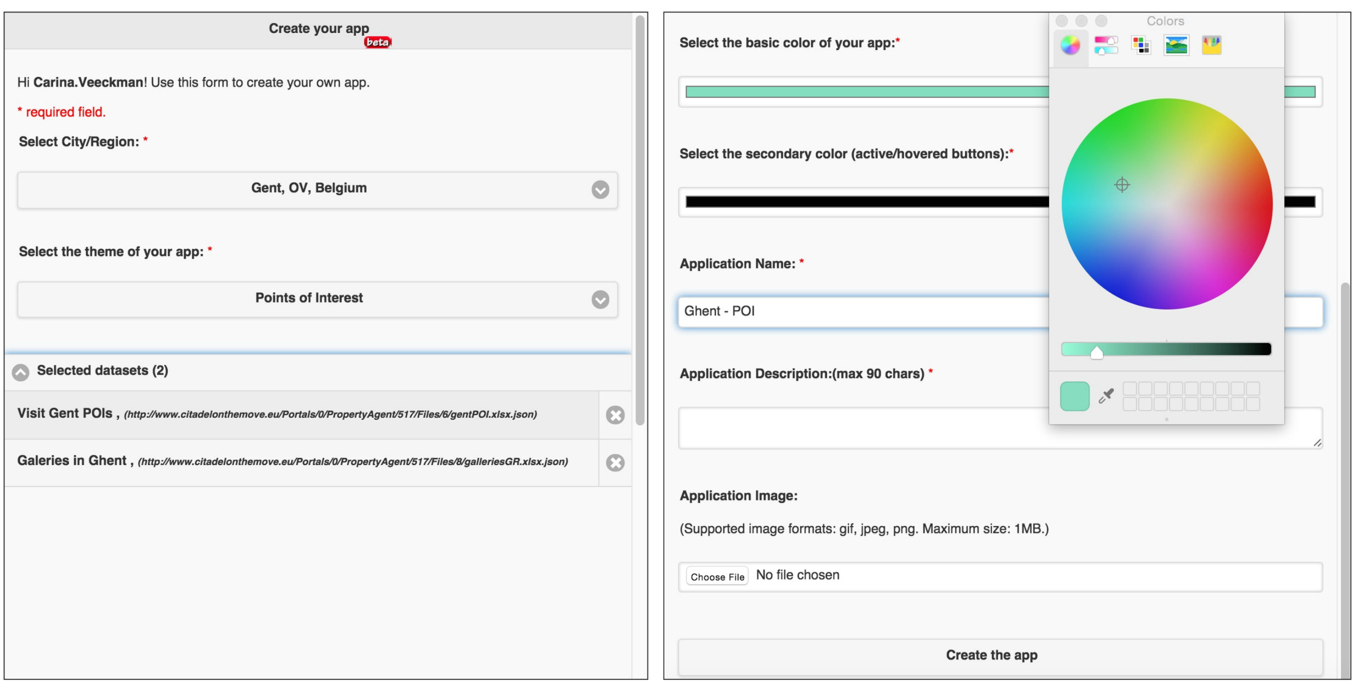

Figure 3. Screenshots of the App Generator Tool

enced users through the download and installation processes. Furthermore, a participatory design workshop was organized in which different stakeholders (e.g., citizens, professional developers, data enthusiasts, thematic experts) were invited. To bridge the "gap" between technical and non-technical participants, simple and creative communication tools were used. In this way, people could easily express themselves by using visual aids, drawings, and so forth. At the end of the sessions, some paper mock-ups were presented that were based on several scenarios. These paper mock-ups were given as an inspiration for the (citizen) developers to start developing new applications (Figure 4).

This tailor-made approach was proven very successful: more citizens were being able to participate and to provide custom feedback. To further engage citizens in the development process, specific "Apps4Dummies"

Figure 4. Paper mock-ups of mobile applications from Athens and Issy-les-Moulineaux

workshops were also organized. In these workshops, a demonstration was given of the different tools, and knowledge was shared about open data and coding in general. At the end of the living lab experiments, 80% of the key users stated that they had learned something new about creating applications in general, and half of them expressed that they are eager to learn more about the topic (e.g., data formats and conversion of datasets). The main conclusion was that the transfer of knowledge and skills proved to be more empowering that just the provision of tools.

Conclusion

This article discussed the findings of four smart city initiatives in Europe, with a specific focus on citizen engagement and the capacities to participate in the public domain. In conclusion, we identify three key lessons learned through this study:

1. The living lab approach facilitates participation
After describing the various roles in the ecosystem, it became clear that the living lab approach played a central role in bringing different stakeholders together. By facilitating *collaboration*, stakeholders came together to jointly create new services, citizens made contact with their administrations, and mutual understanding was created. At the end of the testing cycles, citizens clarified that they better understand the challenges their city is facing, and that they would like to further contribute to the process of opening up data and building applications.

The living lab approach also entailed *iterative* testing and feedback. In the beginning of the project, citizen developers tested and positively evaluated the application templates, although none had the actual intention of developing their own application. This outcome did not fulfill the expectations of the cities: they had hoped to stimulate application development by providing standardized building blocks through the templates. The analyses of the user feedback showed that the users' motivations and the abilities to participate were not fully satisfied. At first, the less skilled users were excluded from the development process, because they did not have the proper skills. Therefore, the cities, as well as the research organization, decided to develop different tools and a more targeted user recruitment and evaluation methodology to optimize the citizen involvement. This targeted approach seemed successful, given that all target groups started using the tools to create new applications. The user feedback was also more satisfactory: the tools were perceived as easier to use and more useful. Furthermore, after the end of the living lab experiments, two-thirds of the users were still using the tools to explore open data or to further improve their application idea. Here, we see that the iterative living lab approach not only proved its beneficial use in bottom-up co-creation, but also in validating the evaluation methodology and monitoring the participation parameters.

2. Co-creation processes can both include and exclude
Next, it became clear that facilitating co-creation processes between citizens and government entities could include some citizens and exclude others. This result was also found in (Turnhout et al., 2010), as one of the unintended consequences of participatory governance. Although it is impossible to involve everyone, the results here showed that, if different tools are aligned with the specific capacities and skills of the users are provided, more chances are created for users to become heard and take part. Interplay could be detected between the collected user feedback and factors influencing the civic capacities to participate. First of all, the iterative testing cycles made it possible to quickly respond to some technical issues and develop a better solution in the next phase. Participants are often frustrated when technical issues occur, and this frustration could evoke a decreasing interest in the long term (with possible drop-outs). But, more importantly, listening to the user feedback and taking the users' abilities and motivations into account, overcame possible failures or low-usage intentions in relation to the technical solutions provided. The development of the App Generator Tool enabled ordinary citizens to easily create applications, and technical skilled users no longer dominated the development processes.

To optimize the involvement, it was also necessary to develop a separate evaluation track for each of the targeted user groups. By making specific questions that matched the profiles of the citizens, the data collection methods were perceived as rather adequate, and not too easy or too difficult to respond to. The creative tools in the participatory design workshops were also very successful in creating "a common language" for communication between the different stakeholders.

3. The approach empowers citizens
One of the most important outcomes for the cities is that, by providing and co-developing the toolkit, citizens were given the opportunity to contribute to the opening-up process of data and to the building of service applications. What in advance was limited to only a few, can now be done by anyone. Citizens acknowledge that, by participating in the diverse evaluation activities and workshops in their cities, they have learned new skills and knowledge, and they can now independently create an application. For the more skilled citizens, the hackathons and other application competitions provided opportunities to network, to disseminate their work, and to exchange experience. For this target group, the motivation of "playfulness" and the opportunity to showcase their expertise and creativity prevailed.

Last, the organization of workshops and peer-learning activities in the community were also vital in supporting the citizens. In the beginning, we observed users who only used the App Generator Tool and then, along the testing cycles, acquired more skills and started to execute more advanced operations. On the platform, the more skilled users also helped the less experienced ones. Catalyzing this mutual support and connecting people with different perspectives thus strengthen civic engagement and the opportunities for creating innovative solutions.

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The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

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The City as Living Laboratory: Empowering Citizens with the Citadel Toolkit

Carina Veeckman and Shenja van der Graaf

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Keywords: living lab, smart city, toolkit, citizen involvement, open government data

A Method and Tool to Support the Management of Systems Engineering Projects

Claude Baron, Philippe Esteban, Rui Xue,
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> *"The problems facing manufacturers can be solved through cooperation, despite differences."*
>
> W. Edwards Deming (1900–1993)
> Engineer, professor, and management consultant
> In *The New Economics for Industry, Government, and Education*

Too many industrial projects still fail, mainly due to the managerial techniques used. Indeed, organizational processes are more or less specifically mentioned in systems engineering standards, but in practice, project managers tend to rely more on their own standards, which sometimes set forth practices that do not align with those of the systems engineering domain, hence the reported discrepancies that very often lead to project failure. Thus, we argue that, to improve the companies' competitiveness when developing new products, cooperation between processes related to system development and project management is key to achieving performance and success. This article presents arguments that tend to support this assertion and introduces an ongoing project to develop both a method and tool that aim to integrate both domains.

Introduction

About one-fifth of the world's GDP, or more than $12 trillion, will be spent on projects each year from 2010 to 2020 (Beer & Nohria, 2000). However, despite this heavy investment, far too many projects – up to 18%, according to the Standish Group International (2013) – will fail. Owing to a widespread lack of project management, only 20% of projects achieve the expected results in terms of quality, costs, and deadlines (Beer & Nohria, 2000). Recent studies have underscored the current partitioning between systems engineering processes and project management practices, leading to competing priorities and trade-offs throughout the course of a project.

Systems engineering and project management are two critical aspects in the success of product development projects (Benjamin et al., 2010; Conforto et al., 2013). The literature suggests that, from the very early stages of projects, the implementation of systems engineering and project management processes is crucial (Sharon et al., 2011). Indeed, developing complex systems is a highly interactive social process involving hundreds of people that have to make joint and consistent decisions (Eppinger & Salminen, 2001). In this dynamic process, product, process organization, and engineering must operate in conjunction. The aim of project management is first to define the project mission and organization, then to determine the budget and plan a schedule, and then to ensure operational control of said project through an assessment of performance by analyzing possible deviations relative to the initial schedule, and to implement corrective actions or new preventative actions if necessary to mitigate risks (Danilovic & Browning, 2007). Its role also consists of organizing and monitoring systems engineering processes.

Companies usually pay attention to these systems engineering and project management processes, but, usually separately: they do not consider connections between them. Indeed, for many years, systems engineers and project managers have thought that their work was separate, focusing more on their own domains than on the whole project (Conforto et al., 2013). However, recent studies have pointed out this unproductive compartmentalization of processes and have

A Method and Tool to Support the Management of Systems Engineering Projects

Claude Baron, Philippe Esteban, Rui Xue, Daniel Esteve, and Michel Malbert

emphasized the need for cooperation between processes at the normative level (Pyster & Olwell, 2013).

Our research objective is thus to elaborate a method and a tool to bridge the gap between these disciplines in order to help project managers detect these inconsistencies and make joint decisions during a system development project. This objective relies on a pragmatic concern, even at the risk of possibly watering down the theoretical recommendations of standards, which is to make them applicable within the company: adapting, scaling to company size, and offering methods and support tools to prime contractors. The main targets are small and medium-sized enterprises (SMEs), for which the deployment of systems engineering processes and the management of complex systems remain practices that cannot easily be harnessed.

The article is structured as follows. First, we describe the current state of industrial practices to introduce the problem addressed and our research motivations. Then, we survey the literature for a methodological solution to align systems engineering and project management processes at the normative level. Next, we propose a method and tool aimed at supporting this alignment and decision making. Finally, we conclude by describing the benefits and future developments of this proposal.

The Need for Cooperation between Systems Engineers and Project Managers

To quickly renew their commercial offer and to reduce development delays, companies have to be proactive and anticipate changes. In the current context of global competition, they have to reduce delays and costs, and increase the offers and the quality of products and services to meet the customers' requirements. The competitiveness of a company thus relies on its capability to master the whole product lifecycle. Consequently, most companies no longer hesitate to collaborate to launch new products on the market. In this field of extended enterprises, it becomes increasingly complex to conduct systems engineering projects given the numerous participants and stakeholders, from the conception to the retirement stage. Systems development involves organizational, financial, human decision-making, logistics, and environmental disciplines, among many others. In the case of straightforward systems engineering projects, it may be sufficient to meet the technical requirements and rely on coherent planning. But, for complex projects, companies will rely on systems engineering and project management guides that allow optimal management of the product lifecycle and the project itself: breaking down the project into tasks and processes, planning tasks and processes with an overall project plan, and monitoring all tasks and processes until the validation of the project (Lee et al., 2008).

Thus, many companies rely on standards and product lifecycle management tools to guide the industrial processes (Rachuri et al., 2008). However, systems engineering and project management standards describe what engineering "best practices", but refrain from saying how to do it. They focus on processes and activities (the "what") rather than on methods and tools (the "how"). On the other hand, according to a study by Pierre Audoin, consulting product lifecycle management tools only helps in the collaboration of technical activities (Nayagam, 2011). Thus, beyond the use of some business intelligence tools (e.g., the SQuORE platform, which is a new-generation tool for optimizing software project management), some major industrial groups develop their own tools to support the enterprise process (e.g., "Unified Planning" at AIRBUS or the "Enterprise Program" at Dassault Systems). These tools, which have been customized to support the companies' own processes, rely on project management standards. However, these tools still do not consider project management and systems engineering processes jointly. Likewise, they do not offer decision-support mechanisms to monitor the project; it will thus be necessary to develop a tool in the near future to implement and coordinate cooperation between the processes of systems engineering and project management and help project management decisions during the systems engineering project.

Support for the importance of developing a tool to integrate the systems engineering and project management can be found in the current economic trend that aims to reduce the cost of activities. Indeed, in a study carried out by McKinsey Global Institute (2013), which ranks the 12 technologies that will most impact the economy by 2025, the "work of the automated knowledge" (e.g., management, engineering, finance) would rank second in the list; the goal would thus be to reduce expenses by about US$ 5,000 billion per annum! This study reinforces our belief that close attention has to be paid to the integration of systems engineering with project management because it is fully in line with current concerns.

Our objective is thus to provide the project manager with a standards-compliant method and tool that support cooperation between systems engineers and managers and their respective processes, to control the project and optimize cooperation between processes. To do this, a first step consists of identifying and modelling systems engineering and project management processes, and then finding the relevant indicators to monitor them. There are three goal: i) to support management by coordinating processes; ii) to offer a method to stakeholders to monitor progress at any time, and at any level, from different points of view; and iii) to provide tools to help them make decisions and explore several directions to guide the project. This tool is designed to simplify and formalize the implementation of the elementary processes proposed by the standards while using the available data, including data generated by tools supporting the business project.

Aligning Systems Engineering and Project Management at the Normative Level

In collaborative engineering, using data exchange, communication, or product lifecycle management tools is not enough to make individuals collaborate; the very notion of role must be revised, as well as processes and interactions between processes, work organization in the company, and mentalities. Business units must cooperate, and what is required is a different mindset, one that redefines professionalism as achieving the mission and having a satisfied customer or end user versus struggling to protect "turf". Systems engineers and program managers bring unique skills and experiences to the programs on which they work (Sudarsan et al., 2005). Those unique capabilities both are essential for the successful execution of the program, as are the skills and capabilities of team members from other disciplines (Langle, 2011). However, there is also a “shared space” where program managers and systems engineers collaborate to drive the program team’s performance and success. Each discipline would then benefit from an understanding of the other’s discipline.

Integrating systems engineering and project management has only been considered since the beginning of the 21th century. Sharon and colleagues (2011) put forward that system engineering management always uses some subsets of project management methods and tools. The technical activities are related to the product domain and the managerial activities are related to the project domain. However, these constitute two complementary facets of system engineering management.

In 2011 and 2012, INCOSE and PMI recognized the importance of integrating systems engineering with project management (Conforto et al., 2013). With the help of the Massachusetts Institute of Technology (MIT), they conducted a survey to better understand the responsibilities of systems engineers and project managers and thus to help organizations reduce program risk and improve their return on investment (ROI). Another objective was to better understand how project management and systems engineering were integrated within the organizations. The results highlighted how critical integration of systems engineering and project management was to alleviate unproductive tension between systems engineering and project management. A guide to help the systems engineers and project managers improve the performance of their programs was provided by Oehmen and colleagues (2012). It indicates four methods to enhance cooperation based on the analysis of several cases to better integrate project management and systems engineering: i) using standards from both domains, ii) formalizing the definition of integration, iii) developing integrated engineering program assessments, and iv) sharing responsibility for risk management, quality, lifecycle planning, and external suppliers

In our study, we conducted theoretical research into the alignment of standards from both domains. We first identified and analyzed standards and guides in systems engineering (i.e., ANSI/EIA 632, IEEE 1220, INCOSE HandBook, and SEBoK) and did the same with PM standards and guides (i.e., ISO 21500 and PMBoK), as listed in Box 1. We concluded that not a single standard or guide contemplates an advanced cooperation between systems engineering and project management, despite the fact that engineers and manager have to cooperate closely throughout all stages of project development. So, we compared and analyzed the differences and similarities between systems engineering and project management standards and guides with the aim of supplementing them during project implementation. We concluded that it may be interesting to adopt ISO 15288 and to include in the process some processes from EIA (Xue et al., 2014a). However, given that suggesting a new release for a standard may involve a long and complicated process, we decided to compare standards and guides from both domains to evaluate which ones could best be aligned. We came to the conclusion that the ISO/IEC 15288 standard could be aligned with the PMBoK quite easily.

Relying on the principle of cooperating standards, we therefore considered the other solutions suggested by the joint study of the INCOSE and PMI: developing integrated engineering program assessments and sharing responsibilities in decisions. This solution is developed in the proposal outlined in the following section.

A Method and Tool to Support the Management of Systems Engineering Projects

Claude Baron, Philippe Esteban, Rui Xue, Daniel Esteve, and Michel Malbert

Box 1. Standards and guides examined in this study

Systems engineering

- ANSI/EIA 632 Processes for Engineering a System (tinyurl.com/ovt45st)
- IEEE 1220 Standard for Application and Management of the Systems Engineering Process (tinyurl.com/prjhjfs)
- INCOSE Systems Engineering Handbook (tinyurl.com/knxx6ct)
- Guide to the Systems Engineering Body of Knowledge (SEBoK) (tinyurl.com/mw4phhy)

Project management

- ISO 21500:2012 Guidance on Project Management (tinyurl.com/yz87lp8)
- A Guide to the Project Management Body of Knowledge (PMBoK) (tinyurl.com/7flker6)

Proposed Method and Tool

The research strategy put forward is motivated by the prospect of improving the companies' competitiveness in the development of new products or services: according to the MIT survey and industrial practitioners, a better linkage between the development of products or services and project management is a decisive leverage in a project's performance (Conforto et al., 2013). Existing project management tools and model-based systems engineering tools fail to communicate and do not provide proactive aid to the control of engineering processes and management of said processes. In a highly competitive economic environment, the development cycle keeps shortening and the search for excellence in engineering project management is one of the main pathways for improving competitiveness along at least two main lines:

1. Acceleration and optimization of the development process from design to prototyping

2. Improvement of increasingly sophisticated project control through enhanced coordination of all actors and processes involved

Indeed, the quality of collaboration between organizations (in the increasingly common case of projects within distributed companies) and between project actors (the latter enacting different roles) is a decisive performance factor. Current corporate practices derive from proposals and recommendations, particularly those highlighted in the PMBoK guide. The various areas of competence that have to be mustered are fully identified in system design project management, including technical and technological (systems engineering, job engineering, innovation-orientated engineering), financial (resources management) and human (skill management), forecast capabilities (planning), corporate and market knowledge, and risk and opportunity analysis. Project management does not intend to develop these different disciplines involved in system design but aims to implement and coordinate them using tools in line with the objectives sought, for the proper advancement of the project. System design PM is therefore a highly multidisciplinary process and, as a result, is a highly difficult one to achieve: corporate experience plays an essential part in the progressive definition of a "proprietary" process suitable for the type of product or service to be developed. This evidence does account for the fact that, although the PMBOK guide recommends a number of practices, project management does not benefit from a genuinely standardized approach. Hence, in practice, companies have to adapt the general recommendations laid down in PMBOK to suit their operating habits and the engineering processes implemented.

In these corporate approaches, we have already defined the main mechanisms that pose an obstacle to the smooth running of the project, including insufficiently detailed or even inconsistent sets of specifications, a priori unjustified (not to say hazardous) technological choices, clumsy resource allocations, insufficiently shared clear, structured, and understandable information. We focus on the problems and deadlocks associated with the fields of detection, analysis, coordination, and decision making: how can an error or insufficient feature be detected at the earliest opportunity? How can the origin be detected in the history of the choices made during the course of the project? How can the best solution – or at least the best corrective action – be chosen?

The approach proposed here consists of relying on the current dynamic aiming at aligning systems engineering with project management to define a generic process for monitored project management. Its originality lies in the choice of monitoring based on the notion of aggregate indicators, coupling information about the system to be built with the system for creating, as recorded in the dashboards made available to all the major project leaders for purposes of tracking, assessing options, diagnosing, and making decisions. In a nutshell, we propose a new decision-making and technical-coordination tool (i.e., a decision model, a formalization of an integrated project and system evaluation process, an indicator dashboard, and a proactive decision-support mechanism), coupling the system development with project management and systems engineering management. We focus on the evaluation, verification, and validation processes, which are poorly instrumented using regular project management or engineering tools, but which form the backbone of the critical decisions made during project reviews.

These proposals are based on previous studies aiming to prove the concept and feasibility of such a tool (Baron, Estève, & Rochet, 2004; Baron, Rochet, & Estève, 2004; Zhang et al., 2012). On the industrial side, a market analysis shows that the industrial tools available only partly meet the needs. These tools belonging to the field of business intelligence have become essential for organizations to identify changes early and to quickly respond and adapt their strategies. However, they are plagued with their own limitations because they fail to provide the overall vision required to address critical issues such as: "How much effort should we undertake to achieve a sufficient level of maturity for the end customer" or "How can I optimize product quality while complying with budget and time constraints?" Thus, the scientific expertise, together with an analysis of industrial needs and existing tools, led us to design a first prototype, named ATLAS, which progressively evolved towards the definition of a more ambitious one, DECWAYS. In the next section, we briefly describe the objectives and results of ATLAS and where DECWAYS stands relative to the first prototype.

ATLAS

The research project ANR/ATLAS (2008-2011) dealt with the connection between project management and product design, as illustrated in Figure 1.

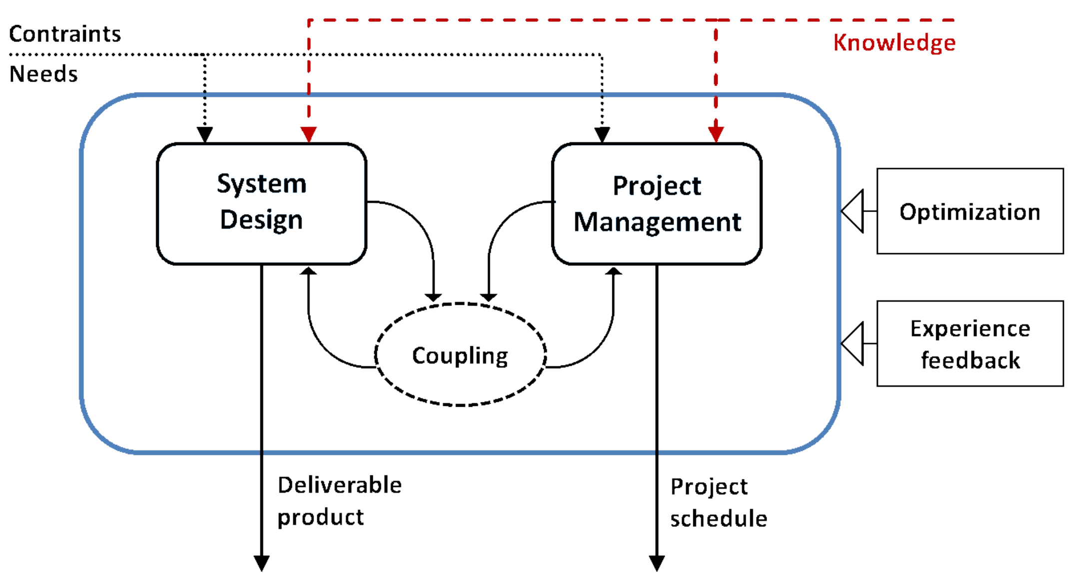

Figure 1. Architecture of the ATLAS platform

These two domains have been the subject of much research over the years, and a fairly wide range of software solutions have been offered (e.g., in project management: Primavera, MS Project, etc; in product lifecycle management: Windchill, Team Center, ENOVIA, etc.). On the other hand, formalizing the relationships that necessarily existed between these processes was a novel idea. It was tested with twenty or so industrialists; the survey conducted revealed a high level of interest in principle and highlighted the expected results (DRIRE, 2009).

Technically speaking, the starting point of the ATLAS project is the EIA-632 standard for engineering a system. This standard allows the project to be broken down into subprojects, leading to a classical tree representation. This decomposition also allows the review of alternative solutions to be memorized for subsequent use when the time comes to opt for a technical solution for the project. With respect to breaking down the project into subprojects and overcoming the difficulty of exchanging data within this tree structure, a key result of ATLAS has been the drawing up of an overall information transmission model between a project and a subproject (Geneste et al., 2009).

However, the main innovation lies in the implementation of two mechanisms coupling system design tools and project management tools, these mechanisms being used to propagate the managers' operational and managerial decisions:

1. Structural coupling: each subproject is broken down into a design architecture and a project management architecture. These two architectures are logically connected to enable an exchange of information.

2. Information coupling: each subproject is governed by requirements distributed between the two architectures, leading in some cases to the definition of common indicators. The most straightforward example is the budget, which, from the design point of view, will be the provisional budget and, from the project viewpoint, the budget available. The dialog between these two points of view is based on the definition of these indicators and on their management.

To become operational, these two coupling mechanisms necessitate a formal decision-making mechanism to be activated whenever a coupling information or communication network modification justifies it. This mechanism had not been defined by ATLAS.

Beyond this, the main results obtained after completion of this project can be identified at various levels and were essentially used to validate the approach in its principle:

1. The establishment of an overall monitoring system shared through dashboards associated with each tree node and displaying the system status: these dashboards summarize the values of various indicators – particularly local ones – and provide the real current data value and an estimated value projected downstream of the project.

2. Conflict management: the conflict arises when one of the two project leaders (i.e., the designer or manager) submits their forecasts to the other, thereby prompting a conflict in respect of the expected indicator values.

3. Managing options as to the different possible technical solutions: at each step, the aim is to identify and characterize one option or a limited subset of interesting options among a number of evaluated options. Thus, at a given tree node, one obtains the list of possible solutions and the integrated values of various indicators for each solution so as to guide the development of the project towards the completion of the selected option.

Also worth mentioning is the inclusion in this approach of various experiences and achievement reuse mechanisms via a database structured by an ontology of concepts encountered during development.

By focusing on the limitations of ATLAS (i.e., versions that are not managed, rigid tree structure that must be homomorphic, validation processes not taken into account, etc.), it became clear that we had to further investigate: i) the methodology used (by conducting a more detailed analysis of the industrial practices and tools); ii) standards (by implementing highly detailed comparative analyses of systems engineering and project management standards); and iii) technical features (by integrating in the computing-platform project new storage technologies, data access and sharing, new interface generations. etc.).

DECWAYS

Within the context of the lack of a common vision in terms of engineering/project management and the necessary multidisciplinary approach that this vision entails during product or service lifecycle, we relied on the results obtained with this first prototype to define a method and specify a tool for supervision, coordination, and control of the evolving stages of a project involving all stakeholders. This proposal truly breaks away from current engineering practices by monitoring the whole development cycle of a product or service from its initial design phase to the prototyping of solutions.

In comparison to ATLAS, DECWAYS offers new proposals:

1. Submitting a generic, high-level project management process that can easily be appropriated by companies, handling multidisciplinary features, and supplementing PMBOK practices. The goal is to promote alignment between disciplines and particularly systems engineering and project management by harmonizing their descriptions of the project notion and its constituent processes, a strategic need as underpinned by the INCOSE/PMBOK alignment (Conforto et al., 2013). In this way, the ATLAS project has been refined to take into account the standardization between project management and systems engineering processes and to exploit the notion of indicators supportive of this alignment.

2. Refining the notion of indicators as language elements common to the disciplines concerned. The aim is to:

   • Highlight indicators allowing one to check how the stakeholders handle any mismatch between expectations and results. These expectations may deal with the system to be built (as viewed from the angle of the product or service) or the system for creating (as seen from the viewpoint of performance, stability, and integrity of the organization supporting the project) (Baron et al., 2009).

   • Show how to construct "aggregate indicators" and "dashboards" providing an overall process supervision capability. The goal is to bring together and promote the use of all data to steer projects and more generally support decision making when managing reputedly highly complex projects.

3. Designing a smart system for an integrated management of a development project relying on the generic process model and on indicators and dashboards to master multidisciplinarity and the project progress; the aim is to:

   • Define mechanisms that provide a genuine aid for taking into account the needs of stakeholders and following-up, verifying, and validating these needs according to the indicators selected.

   • Anticipate and plan the efforts needed, however costly but unavoidable, to check and validate both systems (i.e., the system to be built and the system for creating).

   • Propose mechanisms for tracking any malfunctions by relying more particularly on trend analysis and offering an aid to decision making and longitudinal follow up of the project evolution.

   • Permit exploration of options for guiding the development of systems to be built and the project.

To specify the outlines, objectives, functioning, and services offered by DECWAYS, a first objective was to work towards the alignment of project management and systems engineering process modelling (i.e., needs and requirements engineering, architecture design, system analysis, check and validation) applied to a project. As previously mentioned, Zolghadri and colleagues (2010, 2011) allowed us to analyze the main differences in their descriptions, as well as the roles involved in the process. A comparative study of processes identified the main deviations in their descriptions (Xue et al., 2014b), the roles in either process, and submitted ways and means to make these processes more operational by facilitating their cooperation in practice by looking for and defining the links needed between them (Xue et al., 2014b). This was a prerequisite and a condition for successfully arriving at a generic process of project management that includes coordination, decision making, tracking, analysis, memorizing, follow-up, and correction. Standardizing the process descriptions is one of the means of bringing closer together the systems engineering and project management approaches.

DECWAYS intends to rely on an extended version of ANSI/EIA 632 standard for systems engineering and on the PMBOK for project management (Xue et al., 2014b). As a result, the choice made by DECWAYS lies within the scope of the approach identified in the INCOSE-PMI-MIT project.

However, the analysis goes beyond this result. Indeed, in order to meet our pragmatic concern expressed earlier (i.e., to adapt standards and scale them for SMEs through easy-to-use tools), it was necessary to simplify the organization and the interconnection of processes and to define how and when processes were (or could

A Method and Tool to Support the Management of Systems Engineering Projects
Claude Baron, Philippe Esteban, Rui Xue, Daniel Esteve, and Michel Malbert

be) interconnected and who (i.e., which role) was involved in the company. An option that has already been identified in the ATLAS project consisted of a recursive description of concatenated task batches and in coupling design and management through a decisional model associating the leaders of these two communities. A possible solution in DECWAYS would be to distribute the overall project leadership according to three activities with complementary responsibilities – Executing (Ex), Planning (Pl), Controlling (Co) – relying on a single structural representation of the project (e.g., of the Work Breakdown Structure type). These three responsibilities (Ex, Pl, and Co) share the same obligation, when programming so dictates or when a malfunctioning warning sign occurs, to embark on a discussion and to go ahead only if a decision has been made and if dissemination and memorization have been conducted.

For these activities, the benefit of sharing a common representation lies in the cooperation that it entails and formalizes: at each time step, any discrepancy relative to the original programming will be characterized through use of indicators and the project will only be allowed to continue if the three partners – Ex, Pl and Co – permit. As a potential discrepancy has been characterized, each partner can within their remit analyze upstream requirements that have not been met and find reasons for such a deviation within or without their area of expertise and initiate a dialog with their partners. However, DECWAYS does not interfere with the choice mechanism for decision making: it can either result from a discussion through consensus building or be handled directly by each project leader. What is important here is to record the decision and its context in order to memorize the decision routes and progressively improve them over time on the basis of experience.

In this standardization of systems engineering and project management processes, the second objective is to obtain greater insights into the notion of indicators and deviation. During the task execution, monitoring the evolution of each indicator and checking against the objective will enable an automatic detection of any deviations between the work program initially drawn up and the effective progress in the field.

Operationally, these indicators feature various lifecycles: their definitions, the negotiation between the stakeholders of objective values and related parameters (i.e., thresholds, validity ranges, etc.), and their evolution over time as recorded during implementation. They reflect or are computed on the basis of data, tacit information, and knowledge recorded by the company in its information system (i.e., data originating from enterprise resource planning, data about the project progress and follow-up of the planning tool, etc.). In DECWAYS, the objective is therefore to obtain greater insights into the indicator concept so as to provide it in a multiple-indicator approach (i.e., to express it in a multiple indicator format), with the ability to dialog, to detect danger and drifts, to diagnose and analyze with the ultimate goal of tracing it back to the design and set of specifications, if needed, on the technical and on the organizational side. To do this, we identified several indicators whose function and nature differ: pre-defined "classic" indicators associated with the definition of processes in systems engineering standards and "customized" ones, depending on the project or relative to the company strategy. As in ATLAS, dashboard definition and operator interfacing are part and parcel of the project: given the necessary hierarchical construct of tasks, indicators will be progressively aggregated, which might lead to a multilevel construct of these indicators. Figure 2 synthesizes the main principles of the method and tool.

Conclusion

To develop systems quickly and efficiently, it becomes crucial to align practices in systems engineering and in project management. This issue of systems engineering and project management integration is at the core of economic and industrial concerns. It is also a source of motivation for international standardization organizations, companies, and governments alike.

The DECWAYS method and tool address any inconsistencies that might exist between systems engineering and project management domains, from a pragmatic perspective. It is a follow through on the ATLAS project, which has demonstrated the feasibility of the concept and has served as a prototype to validate the industrial value of these proposals. The tool tackles the issue of collaborative work and project steering conducted in a consistent manner in terms of follow-up and decisions. DECWAYS seeks to offer a method and tool capable of bringing systems engineering and project management closer together, detecting practical divergences, making concerted decisions, and jointly supervising the proper development of the project and system. This article presented the objectives and specifications of the DECWAYS tool, which aims to address this problem. As underscored by the INCOSE-PMI-MIT analysis, a natural means of achieving process cooperation, chosen in DECWAYS, is the use of standards from both domains

A Method and Tool to Support the Management of Systems Engineering Projects
Claude Baron, Philippe Esteban, Rui Xue, Daniel Esteve, and Michel Malbert

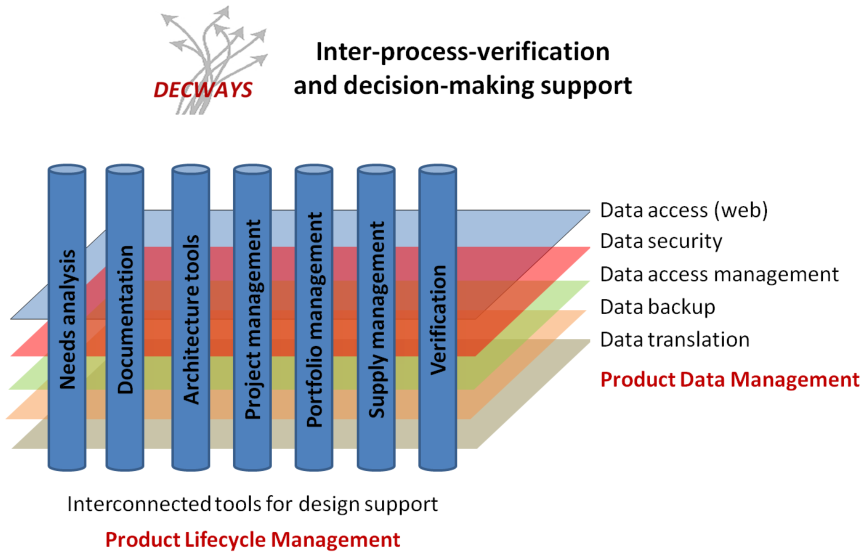

Figure 2. Architecture of the DECWAYS platform

and processes from these standards. But, beyond the mere issue of choosing between the main standards and with the aim of achieving a better match with project management processes, DECWAYS also considers other ways to align processes from both domains such as sharing responsibilities and crossing data towards a collaborative decision process. To do so, it intends to structure collaboration (i.e., between processes, actors, etc.) and provide project leaders and engineers with information produced to assist with decision making. Such a technical and scientific concern fits in well with the current purpose of reducing the cost of intellectual work (e.g., management, engineering, finance) of $5,000 billion annually until 2025 via "smart" software (McKinsey Global Institute, 2013. Thus, DECWAYS should facilitate the management of projects in companies by providing: i) progress visibility, ii) a formal decision-making process, and iii) traceability.

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An earlier version of this article was presented at the 2014 International Conference on Engineering, Technology, and Innovation (ICE), which was held from June 23rd to 25th in Bergamo, Italy. The ICE conference discusses systems engineering as a socio-technical task, with a focus on design of products and services, and the entrepreneurial innovation process for its adoption in society and the economy.

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A Method and Tool to Support the Management of Systems Engineering Projects

Claude Baron, Philippe Esteban, Rui Xue, Daniel Esteve, and Michel Malbert

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Keywords: system design, systems engineering, engineering processes, collaborative engineering, project management, systems engineering standards, decision support

Optimizing Innovation with the Lean and Digitize Innovation Process

Bernardo Nicoletti

> *"It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to management than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely the lukewarm defense in those who gain by the new ones."*
>
> Nicolo Machiavelli (1469–1527)
> Philosopher and playwright

Actionable knowledge to improve innovation and bring value to the customers and organizations is essential in today's economy. In the past, there have attempts to apply Lean Thinking and Six Sigma to the innovation processes, with mixed results. The aim of this article is discuss how to improve innovation processes using the Lean and Digitize Innovation process, which integrates digitization into the Lean Six Sigma method. Through the redesign of innovation processes and their automation, the process aims to add value to customers, improve effectiveness, eliminate waste, minimize operating costs, and reduce time-to-market. This new method is characterized by seven stages, or "the 7 Ds" (define, discover, design, develop, digitize, deploy, and diffusion), with 29 steps. This article describes the Lean and Digitize Innovation process and presents cases where the approach has been successful in helping innovation processes from start to end: from the definition of the value for the customers up to the implementation of a prototype and engineering of the delivery processes.

Introduction

Innovation is crucial to the success of any business. Far too many organizations spend the bulk of their efforts on improving production, finance, and marketing and not enough efforts on improving innovation. Innovation is becoming increasingly more important as the demands of the global economy increase. Organizations need to be agile, current, and smart in order to face the challenges of the changing global economy (Oza & Abrahamsson, 2009; Wilson & Doz, 2011).

Lean Innovation represents the systematic interpretation of Lean Thinking principles relative to innovation in its different forms. There are few systematic implementations of Lean Thinking in innovation management, contrary to what has happened in the production world (Liker, 2003; Schuh et al., 2009). High uncertainties of processes, novelty, and complexity indicate special requirements for the implementation of Lean Thinking in innovation processes. They require holistic rethinking for the implementation of Lean Thinking.

This article focuses on the lean processes, describes their phases, and shows how to use and benefit from the combination of Lean Six Sigma with digitization towards a powerful lean innovation method for improving processes. The method aims to add value to customers, improve effectiveness, eliminate waste, minimize operating costs, and reduce time-to-market through the redesign of the innovation processes and their automation. This approach is increasingly necessary for global success and is an important pre-requisite for success in the lean application of innovation processes.

The Lean and Digitize Innovation process represents the systematic interpretation of Lean Thinking principles regarding to the different types of innovation and development, while also taking into account the possibilities of automation.

Optimizing Innovation with the Lean and Digitize Innovation Process

Bernardo Nicoletti

Review of Literature on Improving Innovation Processes

First, we examine the literature that examines issues connected with the implementation of Lean Innovation. Lean management and innovation are two driving forces of today's business success. However, with fundamentally different concepts, some aspects of lean management may negatively affect an organization's ability to be successful with certain types of innovations.

Subramanyam, Srinivasan, and Prabaharan (2011) applied Lean and Six Sigma to new product development activities. To make the system effective and deliver the design at the shortest time to market with good quality, it is necessary to optimize material cost and design time. Subramanyam and colleagues dealt with an approach associated with the optimization of the above-mentioned problems with the strategy of Six Sigma.

Shuh, Lenders, and Hieber (2009) introduced Lean Innovation and described the core findings of their survey on Lean Innovation at the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen University. Their paper focused on the value system, described its elements, and showed how to use and benefit from the value system towards powerful Lean Innovation. The value system is one core element of Lean Innovation, which is the basis for the value stream design in innovation and development projects. The value system defines, structures, and prioritizes "values" adaptively for one specific innovation project. All relevant stakeholders in the innovation process, such as external and internal customers, define the values considering the organization's strategy and culture. This activity represents the basis for a consequent value-oriented alignment of projects and processes in innovation.

Hoppmann and colleagues (2011) studied the implementation of Lean Product Development . They surveyed 113 product development departments of international organizations. Based on the insights gained from the testing of the hypotheses and the available empirical data, they defined a Lean Innovation Roadmap. They used a novel, two-step methodology called Adjusted Past Implementation. The resulting roadmap for implementing Lean Product Development consists of four major phases and shows the introduction of the eleven Lean Product Development components in the form of eleven overlapping implementation streams. For each of the components, Hoppmann and colleagues defined four detailed characteristics and depicted the time for implementing these characteristics on the roadmap, giving an idea of when to introduce the elements of Lean Product Development relative to each other. For organizations intending to implement a Lean Product Development system, the Lean Innovation Roadmap can serve as a guideline for learning and continuously improving their organizations.

Gerhard and colleagues (2012) investigated the impact of lean principles in innovation-intense organizations, that is, companies of the automotive and machinery industries as well as in research facilities. They suggested that the implementation of lean principles creates positive effects in technology development, for instance, in reducing the development time and increasing the development efficiency. They found that out of the existing lean principles, the two principles of "avoidance of waste" and "flow", have the highest influence on the improvement of development activities

Browning and Sanders (2012) pointed out that, when operations are novel and complex – as in product development, research, information technology, and many other kinds of projects – cutting out the waste turns out to be much more challenging. To understand the impact of lean in an environment characterized by extreme novelty and complexity, these authors drew on their experiences with a number of processes, and in particular Lockheed Martin's lean implementation for the F-22 fighter aircraft. Their find¬ings lead to a path that executives and managers can follow to become lean without compromising innova¬tion.

Chen and Taylor (2009) presented five propositions based on a comparison between the lean culture, lean design, lean supply chain management, and lean human resource management with the characteristics and contributing factors of different types of innovations. These authors discussed different strategies for an organization to achieve the balance and maintain lean and innovation at the same time. They analyzed advantages, disadvantages, and suitable situations for each strategy.

Nepal (2011) extended the new product development literature by presenting a case study of a Lean Product Development transformation framework implemented at a manufacturing firm in the United States. In a departure from typical Lean Product Development methods, they integrated the design structure matrix and the cause and effect matrix into the lean transformation framework. In this way, they allowed analysis of the underlying complexity of a product development system, and thus facilitating determination of the root causes of wasteful reworks. They discussed several strategies to transform the current product development process into a lean process. In order to support the recommended changes in the new product development processes, they recommended a two-phase improvement plan, a new organizational structure roadmap, and a human resources plan. The results of the Lean Product Development show a 32% reduction in product development cycle time due to the proposed new product development process. Nepal's paper also details the lessons learned and the implications for engineering managers based on the case study presented.

For organizations to survive and thrive in today's environment, a key strategy is to leverage innovation capability through an effective process of converting unmet customer needs into successful innovations, thereby creating value for customers, the organizations, and other stakeholders. Welo, Olsen, and Gudem (2012) demonstrated how Lean Thinking could become a precompetitive factor in product innovation through its focus on customer value. The goal of this paper was to determine the applicability of user-centered methodologies in generating inputs that ultimately lead to differentiated innovations. Welo and colleagues presented an office chair case study that implied that, although user-focus is necessary, it will not inevitably lead to novel products, because users are engrossed with past and present.

Lean Thinking can even be used to drive general innovation in organizations (Byrne et al., 2007; Hoerl & Gerdner, 2010). Lean Thinking frees up an organization's resources – people, space, time, and money – such that more resources can be allocated to innovation projects. Another consequence of the application of lean is the support for a fundamental culture shift. Morale will go up when people in an organization start dealing with the complexity in the business. Lean Thinking eliminates or streamlines the processes and products that waste time, that frustrate customers, and that do not add value, thus freeing up the time for people to start thinking about what should come next (Cross, 2012, 2013).

Lean transformation and innovation have both been touted as strategies that are essential to the long-term survival of organizations. The question of whether the two approaches can be used simultaneously remains unanswered. Srinivasan (2010) attempted to derive a theory of lean systems of innovation that combines the notions of lean enterprise trans¬formation with that of innovation. The descriptive understanding of Rockwell Collins, as developed in their paper, draws on publicly available material to support the identification of the key elements of a strategic system of innovation. Srinivasan's analysis highlights the successful use of technology scanning, internal R&D, and open innovation within the innovation system at Rockwell Collins. Furthermore, the existence of a shared value proposition, a strong organizational culture that recognized and rewarded innovation, and the requisite organizational infrastructure serve as key enablers to designing a strategic system of innovation that is reflective of lean enterprise thinking.

Fichman, Dos Santos, and Zheng (2014) adopted a particularly broad conceptualization of digital innovation that allows for a variety of teaching styles and topical emphases for the information system core class. This conceptualization includes three types of innovation (i.e., process, product, and business model innovation), and four stages for the overall innovation process (i.e., discovery, development, diffusion, and impact). Based on this conceptualization, these authors examined the implications of adopting digital innovation as a fundamental and powerful concept in teaching organizations

None of the papers examined in this literature review analyzed the actual process of Lean Innovation projects in depth. Thus, the purpose of this article is to introduce the Lean and Digitize Innovation Process.

Innovation Processes

Innovation can be in the product or the process (Tushman & Nadler, 1986). Innovation can also be relative to organization or to business models (Nicoletti, 2013). Breuer (2013) reports some successful examples of Lean Innovation in venturing (see also Euchner, 2013). Innovation can be classified based on the whether it is incremental or radical (Ettlie et al., 1984), or modular or architectural (Henderson & Clark, 1990). At the heart of the innovation work is the ability to connect the strategy and tactics associated with developing a system of innovation from a macro-per¬spective, with the mechanics of effectively transitioning ideas into products, processes, organization, or business models.

Freeman and Perez (1988) define innovation as the introduction of new and improved ways of doing things at work. In an economic sense, an innovation is accomplished with the first commercial transaction involving a new or improved product, process, or organization of business model. Thus, innovation is restricted to intentional attempts to bring about benefits from changes. These might include economic benefits, personal growth, increased satisfaction, improved group coherence, better organizational communication, as well as productivity and economic measures that are usually taken into consideration. The innovations of technology firms often include technological changes such as new products, production processes, the introduction of advanced manufacturing technology, as well as the introduction of new information and communication technologies (ICT).

Many models have been developed for acquiring a better understanding of the innovation process. These models have ranged from simple "pipeline" or "black box" models to complicated models. Some of them focus on consumer product innovation; others are concerned with industrial innovation. Although numerous models have been developed to describe the innovation process, no model appears to be capable of being used as a generalized model of innovation (Koskinen & Vanharanta, 2002).

Based on observations in the Toyota Production System, Mehri (2006) illustrated some of the negative effects of the lean design process on product innovation. In particular, he underlined that the original Lean Thinking method, rather than allowing open innovation, requires engineers to follow strict flows of design. Due to a product design approach that is heavily based on benchmarking and standardization, internal innovations seem to be impossible. The Lean and Digitized Innovation process allows organizations to overcome this challenge.

Research Methodology

Essential for Lean Innovation is the definition of value for the innovation itself. Therefore, the starting point of Lean and Digitize Innovation is a systematic method to define and handle target values and requirements regarding the innovation as an enabler for a lean development process – the value system. The value system represents a framework for mapping value in a holistic, hierarchical, dynamic, and transparent way (Schuh et al., 2008).

The value system defines, structures, and prioritizes "values" adaptively for one specific innovation project. All relevant stakeholders in the innovation processes, such as external and internal customers, define the values, while considering the organization strategy and culture. It represents the basis for a consequent value-oriented alignment of innovation projects and processes. According to Gudem and colleagues (2013), maximizing customer value is a core principle in innovation, but the value definitions used tend to be based on logical reasoning rather than real-life observations. These authors, based on empirical insights concerning different stakeholders' perceptions of customer value, suggested a redefinition of the functional product value calculation in Lean Product Development. Their method integrates emotional customer value into the traditional model, which is based on minimizing operating costs and reducing time-to-market.

Lean management and innovation are two driving forces of business success. However, with fundamentally different concepts, some aspects of lean management may negatively affect an organization's capability to be successful with certain types of innovations. This article develops a process to minimize such impacts. It is based on combining Lean Six Sigma principles and tools with automation of the innovation processes. In addition, the article discuss different example where this process was successful.

Value system practices focus on market orientation of products and services. Products and services heavily rely on the supply chain process to contribute to the value system. Globalization, competition, and high cost of production influence the value system imperatives. Organizations involved in the value system are challenged with the creation of innovation. ICT can support the improvements in the performance of innovation in many organizations. There are efforts to use ICT as a tool to innovate processes, products, and services for establishing improved management practices to harness better returns on investment and customer satisfaction

Results and Discussion

Several stages compose the Lean and Digitize (short for Lean Six Sigma and Digitize) Innovation process. To be successful, Lean and Digitize Innovation must adopt a process that this article describes as "the 7 Ds: define, discover, design, develop, digitize, deploy, and diffusion. It is essential to apply this methodology and its tools in strong partnership between the sectors of the organization involved, including quality and support departments (such as ICT, finance, or operations) (Nicoletti, 2012). Stakeholders from all parties need to align in setting up and staffing the improvement project team. Perhaps more importantly, the organizations must treat the initial application of the Lean and Digitize Innovation process as the beginning of an iterative cycle that generates continuous improvement and leads to a change in the culture of the organizations towards Lean thinking (Womack & Jones, 2003). A "problem" or "challenge" should not trigger process-improvement efforts. It should be a substantial part of the organizational culture.

It is important to blend process improvement and ICT technology. Based on research and experience, one can profitably use the Lean and Digitize Innovation process. In reference to Lean Innovation, Lean and Digitize Innovation can be summarized as follows. It can be divided into seven stages and 29 steps, as described below and illustrated in Figure 1. At the end of each stage are "toll gates", where the project needs to be checked by the innovation steering committee.

Stage 1: Define
In this stage, the environment is defined to set the ground for the innovation.

1. Context: identify the needs or the requests of the customers, shareholders, and employees, as well as the challenge of competitors and the degree of respect for compliance (e.g., legislation and regulations)

2. Culture: detect the culture of the organization, of the community, and of the nation in which the organization is located

3. Vision: tackle the problems of effectiveness, efficiency, economy, and quality of innovation

4. Strategy: define the possible content of innovation

5. Kick-off: launch the project during a special meeting and notify all the stakeholders

6. Governance: define how to manage the project and set up the team

7. Voice of the Customer: listen to the Voice of the Customers (VoC) associated with the potential innovation and verify it

Stage 2: Discover
In this stage, new ideas are discovered for potential development into a process, product, organization, or business model innovation.

8. Invention: the creation of something new through a organization's own creative process

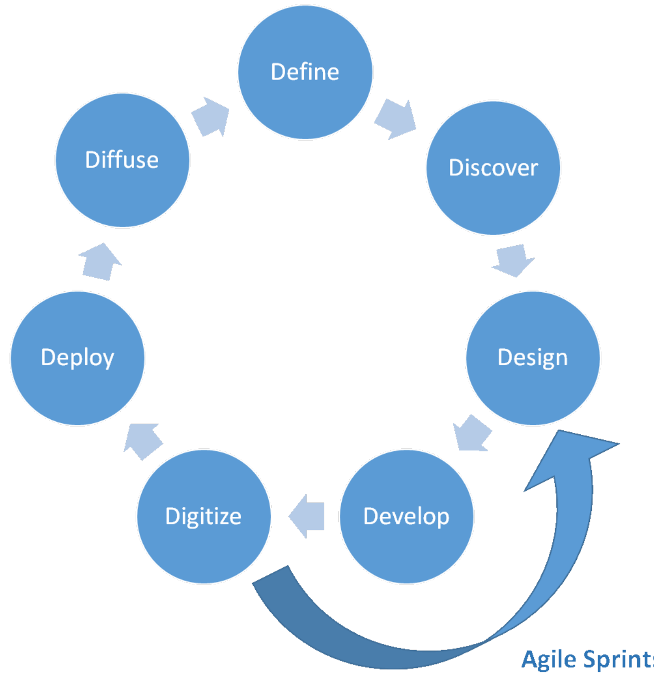

Figure 1. The Lean and Digitize Innovation process and its seven stages, or "the 7 Ds"

9. Selection: finding and evaluating an innovation to potentially develop or adopt

10. Metrics: translate the innovation and the VoC into Critical-to-Quality (CtQ) factors

11. As-Is: map the existing situation in terms of products, processes, organization, or business models

Stage 3: Design
In this stage, the framework and the sequence of activities are defined.

12. Lean: define how to innovate with the support of the team in workshops and meetings

13. Kaizen Plan: define the improvement intervention plan

14. Architecture Design: define the rules, policies, and process structure of the potential innovation

Stage 4: Develop
In this stage, an idea is developed into a usable innovation.

15. Build: construct the chosen solutions

16. Packaging: surround the core technology with complementary products and services that together form a solution that can be effectively used for a given purpose by a target adopter

17. Configure: decide which technology features will be used, whether they will be used as is or with adaptations, how the technology will be integrated with other technologies the organization already has in place, how related organizational elements (e.g., structures, processes) will be changed, and how the organization will absorb and make use of the technology

18. Change management: manage the changes

Stage 5: Digitize
In this stage, the automation is applied at the highest possible level.

19. Implementation: implement the digitized application

20. Test: unit tests, system tests, integration tests, and user acceptance tests should all be conducted

Stage 6: Deploy
In this stage, the innovation is implemented and the ancillary activities are performed.

21. Deploy: implement the chosen solution

22. Document: issue the documents related to the innovation

23. Verify: control the improvements

24. Internal and External Benefits: assess the benefits, both external (i.e., take notice of customers, shareholders, and employees satisfaction) and internal (i.e., assess the profitability, market share, and internal improvements related to the new process)

25. Lessons Learned: learn from the initiative

26. Celebration: acknowledge the team's work

Stage 7: Diffusion
In this stage, it is necessary to assemble and arrange the resources necessary to i) persuade and enable a population of organizations or individuals to adopt and use the innovation and ii) to diffuse or spread it across a population of potential users.

27. Assimilation: when individuals and other units absorb the innovation into their daily routines and the work life of the firm

28. Appropriation: involves such tasks as managing intellectual property and the ecosystem of complementary products and services so that profits are protected from suppliers, customers, and imitators

29. Transformation: the technology and organization to take advantage of the new opportunities brought about by the innovation; transformations can also happen at the market and societal levels

Stages 3, 4, and 5 should be done with an Agile approach, doing several cycles, or "springs" in the Agile terminology. An Agile approach is a development method based on iterative and incremental development, where requirements and solutions evolve through collaboration between self-organizing, cross-functional teams (Socha et al., 2013). It promotes adaptive planning, evolutionary development and delivery, and a time-boxed iterative approach, and it encourages rapid and flexible responses to change. It is a conceptual framework promoting tight interactions throughout the development cycle.

Margaria and Steffen (2010) stressed the simplicity of the Agile approach. Its importance in introducing innovation in software development has been stressed (Aaen, 2008). Brown and Levison (2011) also highlighted how Agile can foster innovation. A similar concept was introduced for instructional systems development (Groves et al., 2012).

The Agile Manifesto is based on twelve principles (Beck et al., 2001). They can be customized in connection with Lean and Digitize Innovation:

1. Customer and organization satisfaction should be pursued by rapid delivery of useful innovation

2. Requirement changes should be welcomed, even late in the innovation process

3. Incremental working innovations should be delivered frequently (e.g., every few weeks rather than months)

4. Incremental working innovations are the principal measure of progress

5. Development should be sustainable; the team must be able to maintain a constant pace

6. There should be close, daily cooperation between business people and the innovation team

7. In-person conversation is the best form of communication (co-location but also virtual teams)

8. Projects should be built around motivated individuals, who should be trusted

9. Continuous attention should be paid to technical excellence and good design

10. Simplicity – the art of maximizing the amount of work not done – is essential

11. Teams should be self-organizing

12. Adaptation to the changing environment is encouraged

Tools

Many tools can be used in conjunction with the process described. They can come from the tools used in Lean, Six Sigma, Agile management, and digitization. This article will not consider the latter ones, because since they are extensive and well covered in many publications. The following discussion does not consider all the possible tools that can be used but only the most appropriate.

One of the best tools for process design is Quality Function Deployment (QFD), commonly known as the House of Quality. It identifies the potential customer value of the innovation based on the customer's (be they internal or external) needs and an innovation's (normally a product) quality characteristics. The analysis through QFD is used to determine when a new innovation is useful, so excess resources are not consumed for innovation that may not be beneficial.

Another useful tool is TRIZ (a Russian acronym for Theory of Inventive Problem Solving). The requirements for innovation can be defined by introducing the TRIZ problem-solving approach in finding innovative solutions to technical problems, especially in product development processes. TRIZ is implemented to define the solutions necessary to improve these processes. The use of TRIZ is beneficial with the lean practice because it efficiently utilizes resources in the system to eliminate waste.

Yamashima, Ishida, and Mizuyama (2005) describe a new method, named the Innovative Product Development Process (IPDP). It systematically integrates QFD with TRIZ and enables the effective and systematic creation of technical innovation for new products. In IPDP, the target products' functions and mechanisms are deployed in parallel into hierarchical structures, and the mechanism that most requires technical innovation is specified from an analysis of customers' needs by calculating a mechanism weight. Then, the technical problems to be solved are defined by considering the relationship between the specified mechanism and corresponding functions or quality characteristics. The application of TRIZ helps in developing the “technical” innovation. The technical innovation of a washing machine proved the effectiveness of IPDP.

Another important tool is prototyping, which is both a culture and a language (Kelley, 2001). Just about anything can be prototyped – a new product or service, a process, even an organization or a business model. What counts is moving the ball forward, achieving some part of a goal.

In the case of product innovations, Digital Mock Up (DMU) is a concept that allows the description of a product, usually in 3D, for its entire life cycle (Subramanyam et al., 2011). The product design, manufacturing, and support engineers work together to create and manage the DMU. One of the objectives is to have important knowledge of the innovation to replace any physical prototypes with virtual ones, using 3D computer graphics techniques. As an extension, it is frequently referred to as Digital Prototyping or Virtual Prototyping. The benefits of DMU are:

1. Reduced time-to-market by identifying potential issues earlier in the design process

2. Reduced product development costs by minimizing the number of physical prototypes that need to be built

3. Increased product quality by allowing a greater number of design alternatives to be investigated before a final one is chosen

There are several practices connected with the Agile approach, such as extreme programming from software engineering, which enables the team to work together to determine goals and shared objectives; the rational unified process from both systems and software engineering because of its iterative development methodology; the focus on eliminating waste from lean manufacturing; and the daily scrum update meetings from product development. These processes enable the innovation team to adapt to changing requirements, reduce the project risk, increase the visibility of team progress, involve stakeholders and learners from the beginning of projects, and speed up the creation of value that the team makes to the business.

Innovation in organizations is important. A key to effective and efficient innovation is the ability to commercialize new products quickly and economically while leveraging the advantages of global outsourcing. The growing role of global outsourcing in innovation represents a paradigm shift that has had a large impact on innovation and commercialization, as noted by Marion and Friar (2012). They explored the use of outside innovation and commercialization resources, from contract employees to short-run manufacturers. They then synthesized their research into four areas where innovation operators could most effectively leverage outsourcing throughout the innovation continuum. Opportunities include developing strong strategic partnerships with outside vendors, using rapid prototyping resources to support agile development, using short-run manufacturers to test products and markets before building to volume, and using expert contractors to reduce fixed personnel costs.

These tools and approaches are helpful for a lean environment because they promote effective and efficient innovation.

Business Cases

The best examples of the Lean and Digitize Innovation process have been tested and implemented in General Electric (Nicoletti, 2006). General Electric teaches innovation operators to use Lean and Digitize Innovation to respect all their processes using a few of the lesser-known lean tools (Immelt, 2012; Prokesch, 2009):

- 7-ways
- Pugh matrix
- Mock-up
- Kaizen
- 5 Why’s
- Right-size machine prototyping

Business success starts with understanding the challenges the customers need to solve. It requires reams of information for answers. However, as data sources proliferate, organizations risk being overwhelmed. The Lean and Digitize Innovation process has proved particularly beneficial in these cases.

Veolia Water – the water division of Veolia Environnement, a French company that is the global leader in environmental businesses that include water, waste, and energy – use sifts through masses of information for business intelligence (Laîné, 2014). Starting in 2007, Veolia Water implemented a program to identify and manage strategic knowledge for competitive intelligence and patent services that help the organization anticipate technological developments and environmental threats and sort information from specialized sources – including databases, websites, and institutional sources and compile targeted information for its experts to analyze.

Not all of an organization's knowledge resides in databases. Each employee's knowledge is even richer, but more distributed or isolated by function. Social innovation technology inspired by Facebook but tuned for business can use employee knowledge regardless of location or role.

When automotive parts supplier Visteon assembled a cross-functional global team to develop a new concept for an automotive component, it used cloud-based social innovation applications that, in a lean and digitized way, facilitate collaboration, idea sharing, and progress tracking (Laîné, 2014).

Misra and Choudhary (2010) presented the efforts of a rug company in the direction of an innovation cycle management to ensure a development-oriented value chain. They developed a framework to examine initially the ICT intervention scenario and then how ICT can mediate in certain areas in the value chain.

Conclusions and Further Research

This article presents a Lean and Digitized Innovation process that has proved very successful in a certain number of business cases. The Lean and Digitize Innovation process is based on the application of several stages described as "the 7 Ds": define, discover, design, develop, digitize, deploy, and diffusion). These seven stages are further divided into 29 steps. The process is based on Lean Six Sigma principles but optimizes the use of ICT systems and agile methodologies to tackle the novelty and complexities in innovation processes.

Optimizing Innovation with the Lean and Digitize Innovation Process
Bernardo Nicoletti

Improving the innovation process is the competitive advantage in innovation-intense industries, as required by today challenging times. The combination of lean and digital technologies helps in making organizations faster and more efficient than competitors, thus creating the basis for competitiveness and future success. In this context, the transfer and application of lean principles and digitization is an appropriate approach to face these challenges.

The Lean and Digitize Innovation process presented in this article has proved successful in a certain number of business cases in manufacturing companies. It would be interesting to consider its extension to service industries, where the digitized components become much more important. Campanerut and Nicoletti (2010) started some work in this direction for the Design for Six Sigma (DFSS), but additional work is necessary.

The Lean and Digitize Innovation process has demonstrated benefits in cases involving product innovation. It seems particularly important to extend its applications to innovation in processes, organizations, and business models. This extension might require modifications to make it successful.

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Optimizing Innovation with the Lean and Digitize Innovation Process

Bernardo Nicoletti

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Do Actions Matter More than Resources? A Signalling Theory Perspective on the Technology Entrepreneurship Process

Ferran Giones and Francesc Miralles

> " *Play on both sides of the board is my favorite strategy.* "
>
> Alexander Alekhine (1892–1946)
> Chess Grandmaster and World Champion

This article studies how technology-based entrepreneurs manage to transform their ideas into viable businesses, regardless of their resource limitations and the complexity and dynamics of technology-intense contexts. To describe how entrepreneurs unlock the value proposition that makes a technology useful, we adopt a set of lenses that allow us to view what happens on both sides of the market. In this context, we need to look beyond the resources to explain the weight that entrepreneur's actions carry on the technology entrepreneurship process. In this article, we use a multiple case study on three new technology-based firms to explore how their actions can be interpreted as valuable market signals. The results suggest that entrepreneurs strategically use market, technology, and social capital signalling to mitigate uncertainty and advance in the technology entrepreneurship process. This research holds implications for academic research on the integration of resource and demand-side views, as well as for entrepreneurs and practitioners interested in understanding the impact of visible actions in the early stages of a new technology-based venture.

Introduction

Technology entrepreneurs are highly regarded as targets of economic policy (Lerner, 2010). The policy expectations on fostering technology-based entrepreneurs contrasts with our limited understanding on how technology entrepreneurship unfolds (Acs et al., 2011). As a result, we often find that initiatives that aim to spur high-growth technology-based entrepreneurial projects fail to achieve the expected results (Shane, 2009).

When considering what makes technology-based entrepreneurs different (see Carbone, 2009), scholars have mostly proposed to decipher what type of resources configurations or combinations would explain the success or failure of the technology innovations of so many promising ventures. Alternatively, innovation management scholars have looked at more subtle elements such as the ability to compensate for the initial technology-push orientation with a demand-pull orientation (Brem & Voigt, 2009), or in other words, to combine the technology potential with a disruptive value proposition (Hahn et al., 2014).

In entrepreneurship research, we might have been using a set of lenses that limits our capacity to see these more subtle elements related to changes in technology or demand orientation. As implied by Alexander Alekhine's quotation at the start of this article, it is difficult to understand and anticipate an opponent's actions in a chess game if you only concentrate on your own view of the board. In the technology entrepreneurship context, scholars focused on understanding firm resources that might be useful when competing to capture value but not have paid sufficient attention to the other side of the board, where actions that are critical in a value-creation context are occurring (Priem et al., 2011).

In this article, we use a multiple-case study approach to explore how the technology entrepreneurship process unfolds in three new technology-based ventures. First, we review the literature relating to the technology entrepreneurship process and signalling theory to make sense of the value of entrepreneurial actions, regardless of the initial resources or characteristics of the firm. Next, we describe our methodology and the three cases we studied. Then, we present our results, especially our key finding: where there is an information asymmetry between the entrepreneur and the potential customers, the use of signals may positively influence the opportunity exploration and exploitation components of the entrepreneurship process. Finally, we discuss the results and highlight their implications for researchers and practitioners.

The Role of Action in the Technology Entrepreneurship Process

The literature review starts with an overview of the technology entrepreneurship process, describing how two of an entrepreneur's main activities – opportunity identification and exploration – are influenced by the technological nature of the opportunity and its context. It follows with the interpretation of entrepreneurial actions as signals, a perspective that could provide some additional information on how the technology entrepreneurship unfolds.

Technology and the entrepreneurship process

In a review of the different definitions given to technology entrepreneurship, Bailetti (2012) found that it typically is seen to involve: i) engineers or scientists operating small businesses; ii) finding an application for a technological advance; iii) a scientific and technical knowledge component; and iv) working with other actors to change technology. In proposing a new definition of technology entrepreneurship, Bailetti (2012) emphasizes value creation and capture: "Technology entrepreneurship is an investment in a project that assembles and deploys specialized individuals and heterogeneous assets that are intricately related to advances in scientific and technological knowledge for the purpose of creating and capturing value for a firm."

To describe how the technology entrepreneurship process unfolds, we reviewed prior literature that describes the main activities of the entrepreneurship process as: opportunity exploration (or identification) and opportunity exploitation (Shane & Venkataraman, 2000). Although simplistic, this two-stage approach helps us to group the myriad of perspectives and definitions on the entrepreneurship process (Moroz & Hindle, 2012), and gives sense to the idea of value creation first, and then value capture second. Thus, using those two main activities or stages as a reference, how does the technological component affect the entrepreneurship process?

The technological component in the entrepreneurial opportunity is observed to introduce additional sources of uncertainty and complexity in the opportunity exploration; technology-based entrepreneurs are often seen to strongly rely on interactions with stakeholders and other external actors to make sense of the opportunity at hand (Giones et al., 2013; Wood & McKinley, 2010). To make progress in opportunity exploration, entrepreneurs need to act (McMullen & Shepherd, 2006). Thus, regardless of the uncertainty and complexity, the technology-based entrepreneur is seen as an active innovator, aiming to put together the market application (or value proposition) with the technology-based product or service they are developing (Hahn et al., 2014).

In this context, we argue that prior experience and knowledge on the technology can help (see Shane, 2000), but its impact will be limited by the rapid pace of change of technology markets and progress in science and engineering. Furthermore, it has been argued that, instead of focusing on pushing the technology to the market, entrepreneurs gain more from getting knowledge from key customers and then tailoring their new products and services to their emerging needs (Yli-Renko & Janakiraman, 2008).

Advancing to the second stage, towards opportunity exploitation, we also find evidence of the specific characteristics of technology entrepreneurship. As happens with established organizations, the entrepreneur faces a situation that can be described as a technology commercialization challenge (see Gans & Stern, 2003). Nevertheless, when it comes to exploiting the opportunity, a startup is in a weaker position than established organizations because the technology, its application, and the newly assembled management team are untested (Shepherd et al., 2000). As a result, overcoming the uncertainty and caution of their potential customers becomes an additional challenge.

Despite the challenges and burdens, we still see technology-based firms emerging, creating new markets, and successfully competing with established players. Therefore, we are induced to look beyond the resources to further understand the technology entrepreneurship process.

A Signalling Theory Perspective on the Technology Entrepreneurship Process

Ferran Giones and Francesc Miralles

Signalling in the entrepreneurship process

If resources alone do not explain the performance of new ventures (West & Noel, 2009), we need to adjust our lenses to also explore what entrepreneurs do with resources and how their actions could actually impact the market (Priem et al., 2011). The first step is to understand that not all actions could convey information that impacts the potential market demand. Using the chess analogy, not every move carries information on the future intentions of that player, and not every move might be properly interpreted by the other player.

Therefore, we are interested in understanding actions that can be interpreted as "quality" signals, that actually convey useful information to the market and stakeholders in general on the internal characteristics of the venture and its products (Connelly et al., 2010). The signalling theory introduced by Spence (1973) – to explain how job applicants would disclose details that were interpreted as signals of their "qualities" to recruiters – has seen more and more applications to explain actor behaviours in management contexts (see Connelly et al., 2010).

Marketing is one of the main research streams that has used signalling theory (Kirmani & Rao, 2000). In marketing research, it is suggested, for example, that information exchanges with stakeholders and potential customers are a necessary precedent to strike on the right actions (perceived as signals) in the definition of the "marketing mix". Closer to the context of technology entrepreneurship, it has been observed that, to reduce the observed information asymmetry between seller and the buyer, the entrepreneur can rely on signalling mechanisms, such as guarantee contracts, to reduce uncertainty and incentivize the first transactions (Godley, 2013). These insights from prior research fit well with the context we are describing: the more innovative the product, and the less known its producer (the entrepreneur), the stronger we expect the information asymmetry will be (Stiglitz, 1985).

We build on the assumption that new technology-based ventures, with no past transactions in the market, no track record of successful product development, and offering untested novel technology products, might have to rely on symbolic elements to convince their potential customers. In this sense, the capacity of the entrepreneur to act (and convey the right signals), regardless of the uncertainty and resource limitations, is expected to provide additional clues to understand the technology entrepreneurship process.

Methodology

The limited understanding of the variables and their causal relationships on the technology entrepreneurship process suggested that we should adopt an exploratory approach. We selected case studies of organizations that would combine the different elements under study: a new venture with a novel technology product targeting a new market. We narrowed our focus on information technology ventures to isolate potential sources of variability related to different industrial contexts and product-service mix. An overview of the three cases is provided in Table 1. Note that all venture names have been replaced with pseudonyms to preserve confidentiality.

We combined different sources of data to build the cases, including in-depth interviews with the entrepreneurs, company presentations, and press releases. The primary source of data was the interviews (one per entrepreneurial venture) that were conducted between June 2010 and January 2011. Each interview lasted between 40 and 60 minutes, with follow-up questions.

Table 1. Descriptions of the new technology-based ventures under study

	Descriptive Variables		
Venture Name	**Product**	**Technology**	**Key Resources**
DigiFasTV	Value-added services to digital television broadcasters	Software to broadcast digital television and middleware for set-top boxes	A strong network including technology and institutional partners
EcoChip	Low-consumption circuits	Designs for elastic clocks in integrated circuits	A leading international research group on electronics
RealSecurity	Software to prevent data leakage	SaaS solutions for data analysis using new proprietary algorithms	Prior knowledge of market and technology and a strong software development team

The interviews were transcribed and coded following theory-building procedures (Corbin & Strauss, 1990).

Following the interviews, we proceeded to write case stories for each venture (Eisenhardt, 1989). We designated the type of signals based on the asset or attribute that was being used to produce the signal. We expected the signals to relate either to the market (i.e., brand, customers, success stories) or to the technology (i.e., patents, unique software or equipment, labs, research profile) In the data analysis process, we found it necessary to add social capital assets (i.e., connections, institutional endorsements, and partners). We labelled those assets in each venture as either low or high based on the descriptions provided by each entrepreneur (low or high).

Results

Using the general theoretical description of opportunity exploration and opportunity exploitation, we describe the data results in Table 2. The data collected shows that: i) there is evidence of information asymmetry between the entrepreneur, the market (i.e., potential customers), and stakeholders regarding the venture and the quality of its products; ii) there is an active engagement by the entrepreneur in the new venture to reduce the described information asymmetry; and iii) an entrepreneur's behaviour can be depicted as a strategic use of signalling to advance their opportunity-identification and exploitation activities.

Evidence of information asymmetry

Although the technology-based entrepreneurs were rather clear on the benefits of their products, they found it difficult to convey this information to the customer, as described by the founder of RealSecurity, who characterized reactions of their potential customers as follows: “You are nobody, you don’t have a brand, (therefore) we cannot work with you”. Furthermore, this information asymmetry challenge is also observed with other stakeholders. In the words of EcoChip's founder, “The investors have no understanding of what our technology is and what we are doing”, exposing that, reluctantly, “we have to prepare messages related to the market benefits of our technology”, otherwise potential investors would not understand their technology solution.

In this sense, the founders of both EcoChip and DigiFasTV would argue that customers demanded additional guarantees that the product will be ready and working: they were asked to “show to third parties that the product was really ready to be used commercially”, as described by DigiFasTV's founder.

Types of signals in the technology entrepreneurship process

Three different types of signals were perceived as valuable by the entrepreneurs: market, technology, and social capital signals.

First, the market signals included actions that were related to raising awareness of the new venture and its reputation. In the words of RealSecurity's founder: “We go to as many events in our industry as we can; it’s exhausting, but we have to do it, and we write regularly in the security and communications magazine – a very technical magazine that everyone reads”. Representatives of DigiFasTV would attend industry tradeshows

Table 2. Signals and related actions of the new technology-based ventures under study

Venture	Signals and Related Actions in the Technology Entrepreneurship Process: Opportunity Exploration	Signals and Related Actions in the Technology Entrepreneurship Process: Opportunity Exploitation
DigiFasTV	*Social capital and technology signals:* Networking and patenting actions	*Market and social capital signals:* Brand building and pilot experiment actions
EcoChip	*Technology signals:* Patenting and R&D progress actions	*Social capital and technology signals:* Venture capital endorsement and R&D progress actions
RealSecurity	*Market and technology signals:* Brand building and promotion of technology updates actions	*Social capital and market signals:* Networking and beta customer actions

even though they still had not completed their first version of the product. Thus, investments in brand development were seen as a valuable signal to their market, despite providing no short-term revenue.

Second, the technology signals were built upon unique technological resource of the new venture; in the case of EcoChip and DigiFasTV the resource was patents. The use of patents as signals would contribute to a market differentiation strategy. As described by DigiFasTV's founder, patents are “the elements that help the market to discern you from the others”. Nevertheless, entrepreneurs would still struggle to convey this information to investors: “The biggest challenge has been to communicate our product – its benefits, and why it would be successful – to the interested investors”, as described by DigiFasTV's founder.

Last, the social capital signals would include endorsements by institutions (public or private), the development and research partners, and even connections with well-known investors. Social capital signals were observed to be used to influence both access to resources and market activation. For example, EcoChip founder's described the value of highlighting ties with venture capitalists: “Investors evaluate their decision based on whether there is another investor with a good reputation in the business”. In a more explicit manner, DigiFasTV's founder mentioned that being part of an incubation program of an engineering university “worked as a public certification that we had the technological and financial resources to complete our technological development”.

Signalling strategies to reduce uncertainty
The entrepreneurs use of different signal types at different moments suggests the potential strategic use of signalling in the entrepreneurship process. In the opportunity exploration activities, we observed that market signals were useful to increase the legitimacy and credibility of the venture; technology signals were used as credentials to access funding resources to sustain the exploration activities; and social capital signals was used to gain access to relevant contacts and to demonstrate legitimacy with institutions.

In the activities related to opportunity exploitation, our cases showed that market signals were used to accelerate first sales, making visible the confidence of the entrepreneur in the long-term quality of its products and services. Technology signals were seen to have a limited effect on sales, but still would be related to an indirect effect on raising the profile of the venture and its ability to stay in the market in the long run. Last, social capital signals were mostly seen in relation to raising the team's legitimacy and demonstrating their performance record. For example, RealSecurity would use the team members' credentials and endorsements to signal the quality of their team.

Discussion and Implications

The findings of this research are in agreement with innovation literature on complex new product development and commercialization (Gans & Stern, 2003). From the perspectives of marketing and signalling theory, the finding that entrepreneurs are seen to use multiple types of signals – strategically selecting what type of content to communicate – opens a potential area of research on the use of signal portfolios (Connelly et al., 2010). Furthermore, the insight that there could be a rational evaluation on the activation of certain signals in relation with some entrepreneurial activities has parallelisms with the strategic-choice literature in relation to entrepreneurship (Ozcan & Eisenhardt, 2009). It also brings further evidence on the often unexpected value of intellectual property in this type of settings (Smith, 2013).

The study is not absent of limitations: there is a need for additional evidence and measures for the signals, for example using a larger sample with a quantitative approach. The sample we used is biased, given that we relied on success stories of entrepreneurs. It would have been interesting to add cases of ventures that failed, and see whether their signalling strategy was related to their failure. In addition, further work is needed to derive objective measures of signals and to enrich the entrepreneur's perspective with views from the market and other relevant stakeholders in the technology entrepreneurship process.

This research contributes to the open call for further integration of the marketing and entrepreneurship literature (Webb et al., 2010). Our findings suggest that market actions such as investments in advertising and brand-building efforts could contribute to legitimacy in exploration activities and accelerate sales in opportunity exploitation activities.

The findings are also valuable for entrepreneurs and agents involved in entrepreneurship promotion. On the one hand, we found evidence of the positive impact of engaging with the market, either to refine the entrepreneurial opportunity or to activate the market demand for the new products and services. On the other hand, we found useful insights regarding the communication strategies that technology-based entrepreneurs can use to shape the expectations of the market and mitigate the risks perceived by their potential buyers or stakeholders. Finally, the findings suggest that investors in technology-based firms should also consider the capacity of the entrepreneur to understand and signal to the market when assessing the potential of a new venture.

Conclusion

The results of the study suggest that new technology-based firms, immersed as they are in the challenge of finding an application for their promising technology, face an information asymmetry with the market. Regardless of the personal reputation and background of the entrepreneur, customers are reluctant to consider a new and untested product from an unknown new venture.

To overcome this situation, we observed that technology-based entrepreneurs rely on their opportunity exploration and exploitation actions, which issue signals to their potential customers and stakeholders. For example, producing market signals (i.e., conveying information on the quality and function of a product), technology signals (i.e., giving visibility to patents and superior technology features), and social capital signals (i.e., gaining public endorsements and displaying institutional ties) were seen to positively affect the transformation of the initial idea into a viable business.

This research holds implications for entrepreneurship researchers interested in extending the current resource-view to study the actions of entrepreneurs in technology-intense settings. It also has implications for entrepreneurs that aim to find alternative strategies to the technology-push and activate market demand for their products.

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A Signalling Theory Perspective on the Technology Entrepreneurship Process

Ferran Giones and Francesc Miralles

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TIM Lecture Series
The Expanding Cybersecurity Threat

Cheri F. McGuire

> *It used to be that not a month would go by without some new data breach being reported. Then it seemed not a week would go by. Today, we see daily reports about some new attack vector, some new cyber-espionage group, some new kind of cyber-attack occurring against our critical networks and our critical data.*
>
> Cheri F. McGuire
> Vice President of Global Government Affairs & Cybersecurity Policy
> Symantec

Overview

The TIM Lecture Series is hosted by the Technology Innovation Management program (carleton.ca/tim) at Carleton University in Ottawa, Canada. The lectures provide a forum to promote the transfer of knowledge between university research to technology company executives and entrepreneurs as well as research and development personnel. Readers are encouraged to share related insights or provide feedback on the presentation or the TIM Lecture Series, including recommendations of future speakers.

The first TIM lecture of 2015 was held at Carleton University on February 19th, and was presented by Cheri F. McGuire, Vice President of Global Government Affairs & Cybersecurity Policy at Symantec (symantec.com). McGuire provided an overview of Symantec's view of the expanding cybersecurity threat and the measures the company is employing to mitigate the risk for companies and individuals. The slides from her presentation are available here (tinyurl.com/m63vk7t).

Summary

To begin, McGuire provided background on Symantec's systems for identifying and evaluating cyberthreats around the world, which it uses as a basis for developing protection measures. In particular, she described Symantec's Global Intelligence Network (GIN), a massive array of monitoring systems, attack sensors, and decoy accounts, combined with the world's largest vulnerability database and capability for big data analytics, which together provide real-time insights on what is happening on a global scale.

Globally, a wide range of threats are being detected across many platforms and devices. There is also wide range of attackers, from highly-organized criminal enterprises to individual cyber-criminals to "hacktivists" (i.e., politically motivated actors) to state-sponsored groups. The variety of threats and motivations make Symantec's task of identifying threats and developing protections an increasing challenge and drives its focus on the attackers' tactics, techniques, and procedures (TTP). A detailed understanding of the attackers is essential in building effective defenses against them.

Today, the key categories of threats raised by attackers are:

1. Data breaches: more than 550 million identities were exposed due to data breaches in 2013, and Symantec expects this number to soon exceed 1 billion, which is equivalent to nearly 1 out of every 7 people on the planet, or about 1 in 3 Internet users. And, data breaches are becoming increasingly broad: intellectual property, trade agreements, and business agreements, are often now the target, not just credit card data, etc.

2. Mobile and social: a key area where threats are proliferating and where social engineering is carried out (i.e., attackers gather personal data about persons of interest via social networks and then use it to make targeted emails more convincing).

3. Ransomware: malware that locks a computer and encrypts the data, then demands payment for decryption. Ransomware is becoming increasingly prevalent: Symantec observed a 500% month-on-month increase in ransomware in 2013.

4. Cyber-espionage: the identity of malicious intruders is not always known, and the distinctions between categories of attackers is not clear-cut: one group may pose as another to obscure their identities and intentions, particularly when the attacks are initiated by nation-states.

5. Internet of Things: innovation in this area is happening very quickly, but the security is a step behind. Symantec believes that, to be effective, security must be built into products as they are being developed, not "bolted on" later.

In terms of targets, McGuire highlighted critical infrastructure (e.g., power grids, transportation networks, manufacturing sectors, financial systems) as an important area of concern.

McGuire also highlighted the increase in web-based attacks: in 2013, Symantec blocked 23% more web attacks than in 2012. However, targeted attacks are of particular concern, such as emails targeted at persons of interest using personal data gathered to increase the apparent authenticity of the communication. Such targeted emails are designed to trick people into taking actions that they would not otherwise take if they understood the consequences. Examples include spear-phishing (i.e., sending an email to a person of interest) and watering holes (i.e., drawing targets to infected websites, where the malware lies waiting to infect visitors).

Beyond Symantec's efforts to develop its products and services, the company has also been actively pursuing public–private partnerships to help counter the expanding cybersecurity threat. These partnerships are both private-to-private and private-to-public; Symantec is working with other companies and with many government agencies that span policy, operations, law enforcement, as well as education and awareness. Such partnerships are motivated by the desire to cooperate and share high-level information, support prosecutions of cyber-crimes, and develop an ecosystem approach to cybersecurity. This approach also reflects the shift towards a defense that is not solely founded on signature-based technologies (i.e., antivirus software), but reflects an increasingly sophisticated, layered approach to cybersecurity.

Finally, McGuire provided a list of best practices for businesses to help protect against cyber-threats:

1. Employ defence-in-depth strategies
2. Monitor for network incursion attempts and vulnerabilities
3. Antivirus on endpoints is not enough
4. Secure websites against man-in-the-middle attacks
5. Protect private keys
6. Use encryption to protect sensitive data
7. Ensure all devices on company networks have security protections
8. Implement a removable media policy
9. Be aggressive with updating and patching
10. Enforce an effective password policy
11. Ensure regular backups are available
12. Restrict email attachments
13. Ensure an infection and incident response procedure is in place
14. Educate users on basic security protocols

TIM Lecture Series – The Expanding Cybersecurity Threat

Cheri F. McGuire

About the Speaker

Cheri McGuire is Vice President for Global Government Affairs and Cybersecurity Policy at Symantec, where she is responsible for the global public policy agenda and government engagement strategy, which includes cybersecurity, data integrity, critical infrastructure protection, and privacy. She currently serves on the World Economic Forum Global Agenda Council on Cybersecurity, and on the boards of the Information Technology Industry Council, the US Information Technology Office in China, and the National Cyber Security Alliance. She also is a past board member of the IT Information Sharing and Analysis Center, a former member of the Industry Executive Subcommittee of the President's National Security Telecommunications Advisory Committee, and a former Chair of the US IT Sector Coordinating Council. Ms. McGuire is a frequent presenter on technology policy issues, including testifying five times before the US Congress on cybersecurity, privacy, and cybercrime. Prior to joining Symantec, she served as Director for Critical Infrastructure and Cybersecurity in Microsoft's Trustworthy Computing Group, and she has held numerous positions in the Department of Homeland Security, Booz Allen Hamilton, and a telecom engineering firm that was acquired by Exelon Infrastructure Services. She was also a Congressional staffer for seven years. Ms. McGuire holds an MBA from The George Washington University and a BA from the University of California, Riverside.

This report was written by Chris McPhee.

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Start by asking yourself:

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