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DESIGN THINKING AND PRODUCT ROADMAPPING IN THE FOURTH INDUSTRIAL REVOLUTION

Design Thinking e Roadmap de Produtos na Quarta Revolução Industrial

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Abstract: : The paper employs the combination of design thinking and product mapping approaches for building key skills and capabilities for technology management during the Fourth Industrial Revolution. It presents an overview of the literature of these two approaches, showing a gap in research that proposes their combination. It defines technology roadmapping planning as a human-centred complex problem and proposes a simple three-step sequence to assess when design thinking is applicable. The paper presents the results of using this approach in a business unit in a private non-profit research and development institute. One is the identification of six different, but interlinked, concepts of technology road-mapping that are relevant to stakeholders. The other is a ―Joint Planning‖ experiment, which suggests that road-mapping planning should rely on the co-creation of all relevant stakeholders and should take place in multiples points of the process, in order to grasp any new learning and context that may arise during the execution of the road-mapping initiative
Key words: Technology roadmapping; Design thinking; Technology management; Technology planning; Product roadmapping

Resumo: Este trabalho emprega a combinação das abordagens de Design Thinking e Roadmapping de Produtos para desenvolver as principais habilidades e capacidades de gerenciamento de tecnologia durante a Quarta Revolução Industrial. Apresenta uma visão geral da literatura dessas duas abordagens, mostrando uma lacuna na pesquisa que sugere sua combinação. Define o planejamento do Roadmapping da tecnologia como um problema complexo centrado no homem e propõe uma sequência simples de três etapas para avaliar quando o Design Thinking é aplicável. O artigo apresenta os resultados do uso desta abordagem em uma unidade de negócios em um instituto privado de pesquisa e desenvolvimento sem fins lucrativos. Uma delas é a identificação de seis conceitos diferentes, mas interligados, de mapeamento de estradas de tecnologia que são relevantes para as partes interessadas. O outro é um experimento de Planejamento Conjunto, que sugere que o planejamento do Roadmapping deve basear-se na co-criação de todos os interessados relevantes e deve ocorrer em múltiplos pontos do processo, a fim de compreender qualquer novo aprendizado e contexto que possam ocorrer ou surjam durante a execução da iniciativa de Roadmapping.
Palavras-chave: Roadmapping de produtos; Design thinking; Gerenciamento de Tecnologia; Planejamento da Tecnológia.

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INTRODUCTION

The Fourth Industrial Revolution brings a "wave of technological advances that are changing the way we live, work, stay alive and interact with each other and machines" (World Economic Forum, 2016a). Much attention is given to demographic and socio-economic drivers of change, such as changing work environments and flexible working arrangements and longevity and ageing societies, or technological drivers of change, such as mobile internet and cloud technology and advances in computing power and Big Data (World Economic Forum, 2016b).

The "revolution" will be accompanied by high skills instability across all job categories, raising concerns on how business, government and individuals will react to these developments, as pointed out by a recent research (ibid), which suggests complex problem-solving will be a core skill in 2020, especially in industries that are expected to become more complex and analytical due to those aforementioned drivers, such as the Information and Communication Technology industry. Overall, social skills, such as coordinating with others, persuasion and service orientation, content skills, like active learning, cognitive abilities, including creativity and visualization, and process skills, like active listening, are becoming more important to the core skills requirements for many industries.

This paper proposes the use of design thinking in technology roadmapping as a path to build the skill sets necessary to create capabilities within organisations affected by the Fourth Industrial Revolution trends. These will require professionals with complex problem-solving skills, and design thinking's approach relies on this core skill. The design approach also depends on creative confidence, which is "the quality that human-centred designers rely on when it comes to making leaps, trusting their intuition, and chasing solutions that they haven't totally figured out yet", building upon active learning and empathy (IDEO, 2015).

The paper focuses on the first phase of roadmapping, more specifically the planning phase. It considers roadmapping as a "product" that needs to be designed taking into consideration the specific context of all stakeholders involved in the technology management inside a firm and also as an opportunity for growth. By doing so, it proposes the use of design thinking as an approach to leverage the flexibility of roadmapping and mitigate the limitations mentioned in the literature, by encouraging systemic thinking, making the process more exploratory, easier to disseminate the results, to evaluate business value and attractiveness of R&D outputs and to be customised, providing clear boundaries and guidelines to each stakeholders, in a reliable, objective and focused way.

This paper is structured as follows. Section 2 combines design and technology roadmapping approaches. Section 3 explains the results of employing such approach in a use case in one technology intensive organisation. Section 4 provides a conclusion and discusses possible future research.

TECHNOLOGY ROADMAPPING PLANNING AS A DESIGN THINKING USE CASE

Technology roadmapping

Technology roadmapping is one of many technology management tools available in the literature and it is mostly related to technology planning and forecasting and technology assessment activities (Çetindamar et al., 2006). An in-depth overview of the literature on technology roadmapping (Carvalho et al., 2013) suggests there are two main benefits from its use by organisations.

The first main benefit is the improvement in the alignment between technology planning and business drivers. It comes from collective knowledge created in the organisation conducting the process when it combines the relative long-term timeframe one takes to appropriate the returns from incorporating a new technology to its product portfolio with the short-to-medium-term timeframe usually considered when identifying market opportunities and threats.

On one hand, the Fourth Industrial Revolution has the potential to make that benefit more apparent, since the demographic and socio-economic drivers of change and the technological drivers of change of the Fourth Industrial Revolution can be combined into technology roadmapping. It aligns technology and commercial perspectives and balances market "pull" and technology "push" (Phaal and Muller, 2009) and as such is it a suited approach to convey such diverse trends from into technology management activities.

On the other hand, those drivers of change from the Fourth Industrial Revolution may have impact on the second main benefit of roadmapping activities: its flexibility and ability to provide relevant results in diverse organisations. Paradoxically, the flexibility it preconizes is often mentioned as one of the disadvantages of employing such technology management tool, since there are no clearly established procedures for the approach and its application may lead to poor results in specific organisations (Carvalho et al., 2013). The limitations of technology roadmapping are: 1) more normative and less exploratory, 2) encourages linear and isolated thinking, 3) difficult to disseminate (Saritas and Aylen, 2010), 4) difficult to evaluate business value, 5) to express a business attractiveness of R&D outputs, 6) to express a business system or operation model (Abe et al., 2009) and 7) to customize the process (Lee and Park, 2005), 8) provides little guidelines, 9) lacks reliability, objectivity (Lee et al., 2009), focus and clear boundaries(Fenwick et al., 2009).

Technology roadmapping initiatives are normally divided in three main phases (Carvalho et al., 2013). The first is preparation, when planning decisions are made. The second is implementation, when initiatives are executed. The third is finalization, when the results derived from the roadmapping are consolidated and disseminated and when go-no-go decisions are made.

The planning phase of any technology roadmapping is the most important for taking into consideration the particular situation and context of any given organisation. To benefit from the flexibility of this technology management tool it is fundamental, when customizing the roadmapping process, "to clearly articulate the business and process objectives and to think through how the generic process of roadmapping might help to achieve the objectives"(Phaal et al., 2001). To do so, stakeholders needs to define the focus of the technology roadmapping or the "unit of analysis" (Phaal et al., 2004), a process that may not be straightforward. It involves defining the external and internal environments, ranging from whole industries to specific market segments or customer groups in the first case, and from corporation-wide, to firm-wide, to business unit-wide, to product family-wide, to specific product, to specific components or sub systems in the second case. The level of detail is also important at the technology level, ranging from a large technology area to specific technologies or engineering and science competences (ibid). Moreover, there are many possible purposes, such as product planning or knowledge asset planning, and formats, such as multiple layers, graphs or flow charts, for the result of a particular roadmapping process. Diverse stakeholders may have different opinions regarding the focus, purpose and format, or may have, what design thinking literature calls (Liedtka, 2011), "unarticulated needs".

As mentioned earlier, the Fourth Industrial Revolution will require complex problem-solving skills, along with social, content and process skills and cognitive abilities. The growing importance of these skills creates opportunities and threats for people involved in technology roadmapping, since they may be the solution or the problem to tackle some of the aforementioned disadvantages of this technology management tool, depending on how organisations will be able to incorporate such skills in the workforce.

Design thinking

One possible approach is to look at the literature regarding the use of design in firms. A review of the literature on the importance of design for firms' competitiveness introduces design as "the cumulative development of an initial creative act which builds up its shaping dimension, that is, the ability to assign a meaning to the design object, and then, its applicative dimension, which translates in the artefact playing a more explicit role in firms' strategy making and innovation practices"(D'Ippolito, 2014). It also highlights how design influences individual behaviours and firm's decision making regarding new product development, emphasising its importance for the definition of consumers' needs, the restructuring of firm's organisational structures and strategies, and the evolution of business models (ibid).

Design thinking is an approach suited for solving complex human-centred problems (Brown, 2008; Liedtka, 2001; IDEO, 2015). Firms can also use this paradigm by approaching managerial problems in the same way designers approach design problems (Martin, 2009). This paper considers technology roadmapping as a highly potential use case for employing design-thinking principles, especially during its planning stage. Technology roadmapping planning can be seen as a managerial problem and an opportunity for improvement and as such can be approached as a result of design.

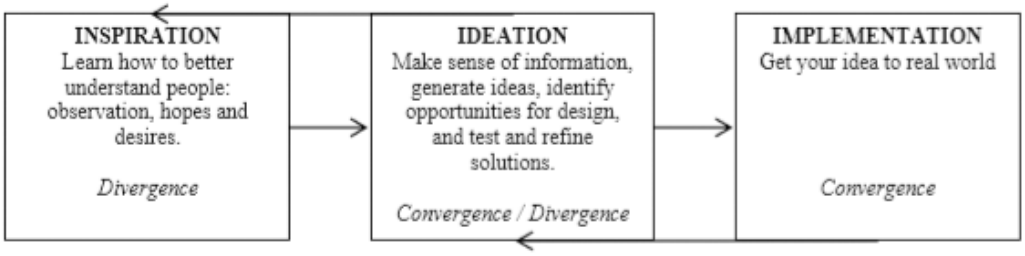

Figure 1 Phased Approach in Design Thinking (based on IDEO, 2015)

Design thinking approaches always depend on iterative processes of continuous feedback loops, throughout a sequence of activities for understanding the object of design, proposing new solutions based on idea generation and testing them in real contexts (Figure 1). The literature on design does not provide any case where design principles have been used in technology management planning processes, or, more specifically, in technology roadmapping. Moreover, the literature in roadmapping planning also shows no discussion on using design principles. Phaal and Muller (2009) propose a roadmapping iterative process with four phases (Figure 2). The first ideation phase determines the scope, designs the structure and type of information of the roadmap and starts with existing ideas. The second divergence phase explores new facts and opportunities, which are narrowed down in the third convergence phase through analysis, when essential elements are chosen to synthesise the strategy to be communicated to relevant stakeholders. Despite the resemblance with design thinking in Phaal and Muller (2009), by mentioning ideation, divergence and convergence, the literature on technology roadmapping does not a practical tool to combine both approaches in the planning phase.

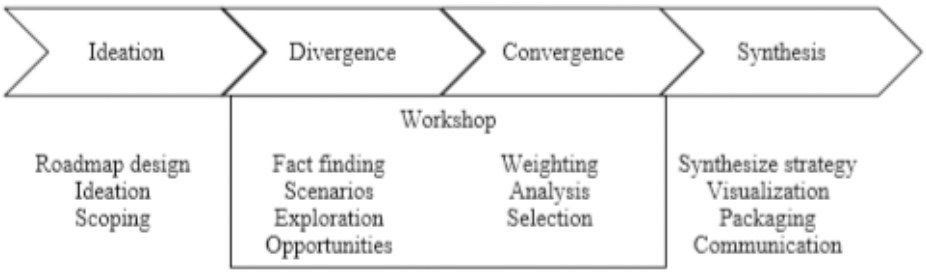

Figure 2 Phased Approach Per Iteration of Roadmapping Process (Phall and Muller, 2009)

Combining technology roadmapping planning and design thinking

Design thinking is an approach to solving problems and exploring opportunities under conditions of high uncertainty, by combining methods that manage risk by placing small bets fast (Liedtka, 2011). Planning a technology roadmapping endeavour can be quite challenging and there are situations when the unique methods of design thinking may be a good approach. In order to assess the applicability of such approach, a simple three-step sequence is proposed: 1) define the designer, 2) link technology roadmapping potential benefits with opportunities for growth and 3) compare the opportunities with design thinking typical environments.

First of all, a single designated person or group of people (committee or steering group) should be in charge of planning the technology roadmapping. This person or group should customise the roadmapping to meet clearly articulated needs from relevant stakeholders. The literature on technology roadmapping suggests many others advantages of using technology roadmapping (Carvalho, 2013), in addition to the ones mentioned in Section 2.1. In order to grasp those benefits, the second step is to rewrite them as opportunities for improvement (or problems) in current technology management processes (Table 1). This has the advantage to clearly define with relevant stakeholders why the technology roadmap is important and what is the opportunity (or problem) for the design. In others words, it creates the first hypotheses for what are the focus, purpose and format of the technology roadmapping being planned.

Table 1 Tool for Linking Technology Roadmapping Potential Benefits with Opportunities for Growth

Advantages of a technology roadmap	Design opportunity or problem to be solved by the design "How can we design a technology roadmapping that…"
Can be utilized as a strategic planning tool	...will be used as a strategic planning tool.
Can help develop consensus among decision makers	...will help develop consensus among decision makers A, B, C and D.
Combines internal development needs with a market-place view	...combines internal development needs in product/technology area A with market B.
Connects the future with the present	...connects current product/technology area A with the future in X years.
Enables assessment of emerging technologies from the learning obtained	...assesses emerging technologies A and B.
Establishes of a shared product-technology strategy	...establishes a shared strategy between product A and technology B.
Focuses on discussion around specific steps of the process	...focuses on the stage X of product/technology Y development process.
Focuses on longer-term planning	...focuses on the next X decades.
Focuses on planning with priority setting	...is based in shared priorities between decision makers A, B, C and D.
Improves the communication and ownership of plans	...improves the communication between decision makers A, B, C and D.
Improves the time-to-market and time-to-money	...delivers product/technology A in X years with $ revenues in Y years.
Improves the dialogue between projects and vehicle programs	...improves the dialog between project A and program B.
Provides a means for the development of advanced technologies	...provides the means for the development of advanced technologies A and B.
Provides a mechanism to help experts forecast science and technology	...helps decision makers A and B forecast S&T in areas X and Y.
Provides a simple method to solution complicated issues	...find the simplest method to solve issues A and B.
Provides a visual map	...results in a visual map with information X, Y and Z.
Provides an direction	...provides a direction for A.
Provides an extended look at the future	...focuses in X years.
Provides high information content in one single figure	...results in information content that can be understood in one single figure.
Provides information to help make better science and technology (S&T) investments	...provides information to decision makers A, B, C and D make investments in S&T areas X, Y and Z.
Stimulates the learning and communications	...stimulates learning and communications between stakeholders A, B and C.

With the clearly defined opportunity, the person (or group) in charge should take the third and final step and assess whether or not design thinking is the right approach. Adapted from Liedtka et al. (2014), Table 2 provides a straightforward tool to assess when design thinking should be used in technology roadmapping.

Table 2 Tool for Technology Roadmapping and Design Thinking Assessment

Question	Design thinking is appropriate for roadmapping if…
Is the problem human-centred?	There are many people involved in roadmapping. It is possible and important to have deep understanding of the actual people (users) involved in roadmapping.
How clearly do you understand the problem itself?	There is a potential opportunity behind roadmapping, but it needs to be explored and get agreement from diverse stakeholders. The problems inherent to the roadmapping activities are not clear and need further investigation.
What's the level of uncertainty?	There are many unknowns (large and small), and past data is unlikely to help planning the roadmapping activities, since it is not a good predictor of the future outcomes of the roadmapping.
What's the degree of complexity?	There are many connecting and interdependent facets of the roadmapping activities, making it hard to know where to start. The path to conduct the roadmapping is not clear, and analytic methods have not succeeded in solving similar roadmappings in the past.
What data is already available to you?	There is very little relevant existing data to analyse.

The following steps should follow any design thinking approach the designer or designated group in charge feel more comfortable with. There are many available, such as IDEO (2015), Liedtka et al.(2014) and Vianna et al. (2012). The next session shows the results from using the approach presented in Liedtka et al. (2014), simply because it is a step-by-step practical approach familiar to the author of this paper. Nevertheless, any other design thinking method should provide similar results, since they all derive from the same design sequence - understanding the opportunity at hand, idea generation to propose new solutions to the problem and testing them in real contexts - with continuous feedback loops.

Design of an Integrated Product Roadmapping Plan

This section presents the main results from adopting Liedtka's step-by-step project guide (Liedtka et al., 2014) in one business unit (BU) of CPqD, a private non-profit research and development institute in Brazil focused in information and communication technologies. Table 3 shows the results from the first step of such guide, "Identify an Opportunity", in which the tools presented earlier were adopted to conduct the activities of defining a designer and learning from stakeholders whether or not design thinking was applicable.

Table 3 Applicability Assessment of Design Thinking Approach in Roadmapping Planning

Design step	Activity	Deliverable
Step 1: Identify an Opportunity		
1.1: Define the designer or group of designers	Define the designer or group	Designer appointed by BU director
1.2: Technology roadmapping potential x Opportunities for growth	Interviews with stakeholders (business unit director, product development managers, technology development managers and product marketing managers) regarding: 1) past roadmapping experience: implementation, purpose, benefits, usefulness 2) opportunity for the new roadmapping 3) scope of the new roadmapping	First hypotheses for focus, purpose and format (Table 1 and Table 2 tools)
1.3: Design thinking match	Learning from interviews	Go-no-go decision

The first column in tables 4, 5 and 6 identifies each of the remaining steps in the design approach, considering the three phases of design thinking projects mentioned in: inspiration (Table 4), ideation (Table 5) and implementation (Figure 6). The second column lists the main activities performed during the execution of the proposed design process.

The third column provides the deliverables of each design step. Table 4 resumes from Table 3 and starts with the second step of the adopted guide, "Scope Your Project", when new learning takes place and the first hypotheses are confronted with the evidence gathered from iteration with stakeholders.

Table 4 Activities and Deliverables for Each Design Step of Roadmapping Planning during Inspiration

Design step	Activity	Deliverable
Step 2: Scope Your Project	Presentation of hypotheses for focus and purpose to BU director	New hypotheses for focus, purpose and format
	Learning from feedback	
Step 3: Draft Your Design Brief	Presentation of a Design Brief to BU director including project description, scope, target users, exploration questions, expected outcomes and success metrics	Design Brief
	Learning from feedback	
Step 4: Make Your Plans	Creation of a Research Plan	Research Plan and People Plan for 7 stakeholder groups
Step 5: Do Your Research	Ethnographic interviews with 5 stakeholder groups	Summary of 27 interviews and 75 questionnaire answers
	Job to be done interviews with stakeholder with 5 stakeholder groups	
	Online questionnaire with 2 stakeholder groups	
	Summarizing	
	Presentation of summary to BU director	
Step 6: Identify Insights	Creation of job-to-be-done and empathy posters for each stakeholder group	7 stakeholder posters
Step 7: Establish Design Criteria	Creation of design criteria for each stakeholder	8 Design Criteria (one for each stakeholder and one overall)

Table 5 Activities and Deliverables for Each Design Step of Roadmapping Planning during Ideation

Design step	Activity	Deliverable
Step 8: Brainstorm Ideas	Brainstorming session with selected stakeholders in order to identify solutions to problems detected in the Design Criteria	481 ideas for stakeholder groups
	Summarizing	
Step 9: Develop Concepts	Brainstorming session for identification of concepts	6 concepts identified
	Interlinking concepts	Roadmapping process interlinking all concepts (Figure)
Step 10: Create Some Napkin Pitches	Creation of format for summarizing and communicating new concepts	1 Napkin Pitch for "Joint Planning" concept
Step 11: Surface Key Assumptions	Thought experiment with Napkin Pitch in terms of value, execution, scale and defensibility	Experimentation plan for "Joint Planning"
Step 12: Make Prototypes	Development of simulation experiment with storyboards for each stakeholder	7 simulation experiments for "Joint Planning"

Table 6 Activities and Deliverables for Each Design Step of Roadmapping Planning during Implementation

Design step	Activity	Deliverable
Step 13: Get Feedback from Stakeholders	Interview with each stakeholder to collect feedback from the simulations experiments	Live experiment proposal for "Joint Planning"
	Learning from feedback	
Step 14: Run Your Learning Launches	Execution of live experiment where all stakeholders establish the focus and purpose of the new roadmapping	Workshop for "Joint Planning"
	Learning from feedback	

One relevant result from the design process is the identification of six different concepts that are relevant to one or more stakeholders of the technology roadmapping initiative and are somehow interlinked with one another. One of them was called "Joint Planning" and was the most relevant, since the objective of the design process was to identify a solution to the roadmapping planning problem. The others were "Creation", which is the subprocess necessary to create the content, or in other words, the roadmap itself. This concept considers workshops will all stakeholders as the proper tool to create specific moments for stakeholder engagement and collective learning, but the content should have different formats, according to what is needed by each specific stakeholder's job-to-be-done and persona, which is the input to the concept "Use of the map", in which strategic alignment is set as the basis for decision making by each one, and to the concept "Execution", which is dedicated to assuring one solution to monitor the roll-out of the decisions defined in the roadmap. Some concepts are also inputs to the "Divulgation" concept, since all stakeholders have a desire to have "Updating" should establish the policies and procedures do identify when a roadmap should be updated and the whole process, or parts of it, be restarted. The interlink between all concepts created during the design process is presented in Figure 3.

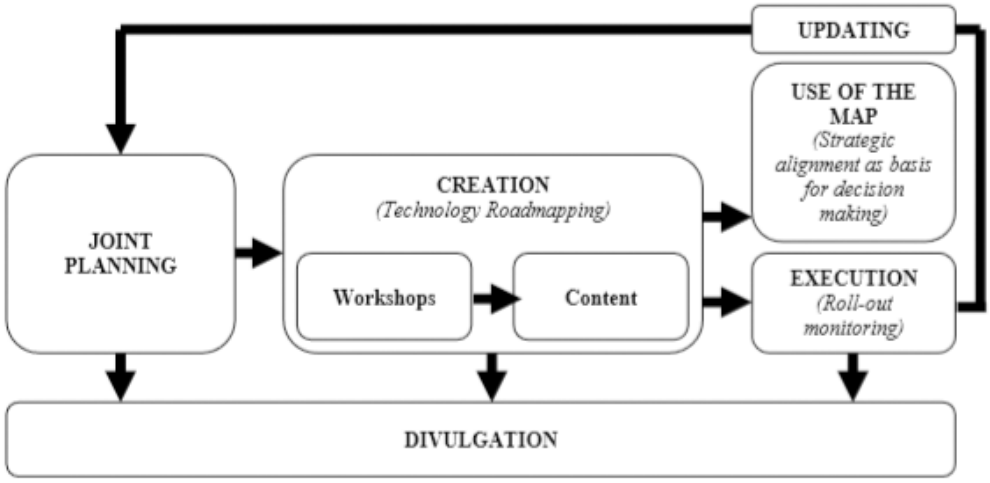

Figure 3 Result of the Roadmapping Planning Design

Another relevant result is the "Joint Planning" live experiment. The concept behind this experiment is a collective view from all stakeholders that roadmapping is a process that needs to be planned with the help from all parts, in which everyone helps defining roles and responsibilities, participants, focus, content to be generated, and how divulgation, execution and updating should be made. In short, the "Joint Planning" concept considers that any solution for the roadmapping planning stage is expected to define the design criteria for all the other six concepts. This is in line with the roadmapping literature that defines the planning stage as the most important in the roadmapping process. Moreover, the live experiment takes one step further in the technology roadmapping literature by suggesting that the planning stage should be broken into many planning stages along the roadmapping process. The first planning initiative takes place at the beginning of the process and focus on setting the purpose, focus and participants, which is not new. The innovation is on multiple planning stages between each step in the "Creation" concept and between all other concepts. For instance, for each workshop inside the "Creation" concept, a planning workshop should be made to define participants, roles and responsibilities, preparatory material and resulting material for the next stage. Again, nothing new, except for the fact that these multiple planning workshops consider the "Joint Planning" criteria, which rely on the co-creation of all relevant stakeholders and not only the personal point of view of a single process owner or stakeholder group. Moreover, such multiple planning workshops allows the use of any active learning that takes place during the execution of the roadmapping, since new knowledge may be created and stakeholders context may change. Although Figure depicts "Joint Planning" as a separate box, it actually takes place throughout all other concepts in the black arrows.

The live experiment was a half-day workshop with the participation of all stakeholders, after which a feedback questionnaire was sent. The results of this questionnaire were a Net Promoter Score of 32% with positive feedback regarding 1) alignment between different stakeholders, 2) integration of the technology development initiatives, 3) longer term planning, 4) contact with a new methodology and 5) synthetic format for presenting a large amount of information before starting the next phases of roadmapping. However, there were mixed feelings among participants around the duration of experiment and the level of technical details presented.

CONCLUSION

The Fourth Industrial Revolution will bring high skills instability across all job categories in terms of complex problem-solving, social, content and process skills and cognitive abilities. The paper proposes the design thinking human-centric approach as a path to build such skills and abilities in technology roadmapping initiatives, and also to leverage the flexibility of roadmapping by mitigating the typical limitations of such technology management tool.

A simple three-step sequence is proposed to kick-off the first phase of roadmapping: the planning process. These are defining the designer, creating the first hypotheses for purpose, focus and format with the involvement of stakeholders, and assessing whether or not the design thinking approach is appropriate.

The use case identified six different, but interlinked, concepts of technology roadmapping that are relevant to stakeholders: “Joint Planning”, “Creation”, “Use of the map”, “Execution”, “Divulgation” and “Updating”. The design also resulted in a “Joint Plannin” experiment, in which all relevant stakeholders co-created the design criteria of all other concepts. It is also based on multiple workshops, in order to grasp any new learning and new context that may arise during the execution of the roadmapping initiative.

Further research may be needed in order to verify is this approach brings results with better quality than traditional ones. Qualitative and quantitative research should propose and measure comparable performance indicators. Another field of research should go the direction of creating a framework for assessing whether or not new skills and abilities for technology management in the Fourth Industrial Revolution are being created and if they provide improvements in organisations using design thinking approaches. This is one limitation of this research, since it is not based on a thoroughly correlation between those skills and abilities and the ones developed by building design thinking competences in the people involved in technology management.

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