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The Digitalisation of Roadmapping Workshops

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Abstract

Roadmapping lacks development regarding the application of digital tools. Although roadmapping software is analysed in the literature, it does not address the people-centric characteristics required in workshops. This paper investigates the digitalisation of roadmapping workshops using a psychosocial framework (cogitate, articulate, and communicate). Three research phases were conducted to analyse workshops that replaced physical tools (paper charts, sticky notes, and stickers) with digital tools (interactive display, personal computer, and whiteboard software). The results of this study show that the digital tools used can support co-located roadmapping activities, delivering potential improvements, particularly for creating strategic narratives in the articulate stage.

Keywords: roadmapping, workshop, digitalisation, digital, software, whiteboard, sticky-note, interactive display

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Abstract

Roadmapping lacks development regarding the application of digital tools. Although roadmapping software is analysed in the literature, it does not address the people-centric characteristics required in workshops. This paper investigates the digitalisation of roadmapping workshops using a psychosocial framework (cogitate, articulate, and communicate). Three research phases were conducted to analyse workshops that replaced physical tools (paper charts, sticky notes, and stickers) with digital tools (interactive display, personal computer, and whiteboard software). The results of this study show that the digital tools used can support co-located roadmapping activities, delivering potential improvements, particularly for creating strategic narratives in the articulate stage.

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1. Introduction

Technology-Roadmapping (TRM) or Roadmapping is acknowledged as a valuable strategic management and planning approach for technology and innovation (Park et al., 2020). Roadmapping enables organisations to deal with complex and uncertain organisational and innovation challenges using simple, people-centric, collaborative, and multifunctional techniques. These characteristics are interconnected and emphasised as a core advantage of roadmapping. They allow participants to focus on gathering critical information, defining strategic plans and reaching consensual decisions in complex and uncertain contexts with multiple and multidisciplinary stakeholders (Kostoff and Schaller, 2001; Phaal et al., 2004).

Since firms started to report their roadmapping endeavours in the 1990s, managers have introduced structured, systematic and agile methods to roadmapping processes, largely based on engineering and agile approaches (Carvalho et al., 2013; Simonse et al., 2015; Vatananan and Gerdsri, 2012). However, digitalisation is still a relevant approach that roadmapping has faced challenges to adopt (Schimpf and Abele, 2019).

Digitalisation refers to the use of digital technology to create and improve value for businesses, organisations and society (Farrington and Alizadeh, 2017; Gobble, 2018; Lanzolla and Anderson, 2008). Although there are studies related to software for roadmapping, those found by this research do not seem to have accomplished the digitalisation of roadmapping (Abele et al., 2018). Rather, these examples describe software solutions closer to project and product management systems used to manage organisational processes and information. Therefore, these systems appear to have limitations related to collaboration activities and the people-centric characteristic of roadmapping.

The impact of digitalisation goes beyond roadmapping. Digitalisation is a relevant trend for technology and innovation management (Farrington and Alizadeh, 2017; Iansiti et al., 2018). Companies have been required to review and update their management processes to create value and remain competitive by means of addressing digital technologies (Agostini et al., 2020; Hansen and Birkinshaw, 2007). Farrington and Alizadeh (2017) pose three main digitalisation lines to be considered: digital collaboration, virtual experimentation and simulation, and big data. They also describe the potential implications that digital technologies may incur to business models and operations.

Roadmapping plays a significant role in technology and innovation management processes, supporting strategic technology and innovation planning (Daim et al., 2019; Phaal et al., 2004). Thus, the digitalisation of roadmapping contributes to its broader management processes. In particular, roadmapping contributes to the adoption of digital technologies that support digital collaboration because of its collaborative and people-centric characteristics.

The characteristics of collaboration and people-centric roadmapping are associated with highly interactive workshops based on simple visual tools and group working (Kerr et al., 2012; Phaal et al., 2004). In fact, workshops are often perceived as the roadmapping process itself, especially in 'fast-start' approaches, despite the importance of pre- and post-workshop activities (Gerdsri et al., 2009; Kerr et al., 2019; Phaal et al., 2007). Therefore, the digitalisation of roadmapping requires careful consideration of the digitalisation of workshops. Despite the current achievements of digital technologies in terms of usability, performance, and virtualisation (Cascio and Montealegre, 2016), little to no theoretical and practical guidance is available to address the digitalisation of roadmapping workshops.

Moreover, roadmapping workshops are frequently conducted as strategic episodes isolated from the business operations. The difficulty of implementing roadmapping results into organisations (Hirose et al., 2020; Phaal et al., 2005) aligns with the "effectivity paradox" discussed in the literature that investigates strategy workshops (Healey et al., 2015; Hodgkinson et al., 2006; MacIntosh et al., 2010). According to MacIntosh et al. (2010), the development of strategy workshops disconnected from the daily operations creates a productive result in terms of rethinking the current business model and identifying new opportunities. However, because of the lack of alignment with the existing operations, organisations struggle to translate the results from off-site strategy workshops into actions that can be implemented back into business operations.

Roadmapping workshops and strategic episodes are both activities developed to cope with the exploration of new opportunities and formulation of organisational strategies (Hodgkinson et al., 2006; Phaal et al., 2004). They seem to differ mainly in the information scope and granularity. The strategic episodes as part of strategic processes are often oriented to deal with overall business and operations strategies (Hodgkinson et al., 2006), while workshops as part of roadmapping processes tend to be oriented to technology and innovation strategies and plans (Phaal et al., 2004). However, if results from roadmapping workshops and strategic episodes are to be compared, it is likely that there are frequent overlaps and interconnections. Indeed, a roadmapping workshop could be seen as a strategic episode in many ways. Even though workshops in roadmapping and strategic episodes seem to be dealing with similar objects, these two bodies of literature seem to lack integration.

This paper presents the results of a research project that explores the introduction of digital tools into roadmapping workshops. It focuses on answering the question: 'To what extent and in what ways can replacing physical tools with digital ones enhance roadmapping workshops?' To this end, three research phases were conducted. They investigated roadmapping workshops, which were digitalised by changing their core tools from physical (paper chart, sticky-notes, and stickers) to digital (interactive display, personal computer, and whiteboard software); while keeping their simple, visual, and people-centric characteristics.

The following section presents a literature review about roadmapping activities and characteristics, including studies that addressed software for roadmapping and the application of digital tools to general workshop activities. Then the research method, phases, and findings are described and discussed to clarify whether the current performance of digital technologies can deliver a digital

roadmapping workshop. Finally, conclusions are drawn, and opportunities for future research are proposed.

2. Literature review

2.1 Roadmapping activities and characteristics

Roadmapping is a well-established management approach used for several purposes in the context of strategic and innovation management (Simonse et al., 2015). Product-technology planning and strategic planning represent its most relevant contributions (Park et al., 2020; Phaal et al., 2004).

Literature shows that roadmapping processes have initiation, development, and implementation activities in common, underpinned by a referential framework, the roadmap (Albright and Kappel, 2003; Gerdsri et al., 2009; Willyard and McClees, 1987). Initiation activities refer to defining the unit of analysis, selecting participants, and setting the agenda. Development activities include the selected people working as a group to brainstorm, generate and agree on content before articulating strategies using the roadmap. Implementation activities include transferring results from roadmapping to the business or organisational context to deliver the value created into practice.

Despite the relevance of the roadmap as a leading framework, the roadmapping process is acknowledged as the core value (Phaal and Palmer, 2010). Roadmapping processes have social and cognitive characteristics derived from the use of workshops and the application of simple and visual tools that make roadmapping unique compared to other management approaches (Kerr et al., 2012; Kerr and Phaal, 2015). For example, knowledge creation and sharing are underpinned by democratic brainstorming and discussions; and consensual decisions are achieved by aligning interests from different business perspectives.

Kerr et al. (2012) have proposed a psychosocial framework comprising three stages – cogitate, articulate, and communicate – to explain how cognitive factors and social iterations are addressed in roadmapping activities. Cogitate refers to brainstorming ideas by roadmapping participants, while articulate represents the development of sense and meaning of existent information towards the roadmapping objective. This stage uses the roadmap architecture to support the visual analysis required for dealing with multiple and connected information. Communicate represents the approach to transfer results from the articulation stage to roadmapping stakeholders. Thus, communication patterns need to be designed to allow stakeholders to understand the proposed message through the roadmap and other supplementary objects delivered as part of the roadmapping effort. This framework is depicted in Fig. 1.

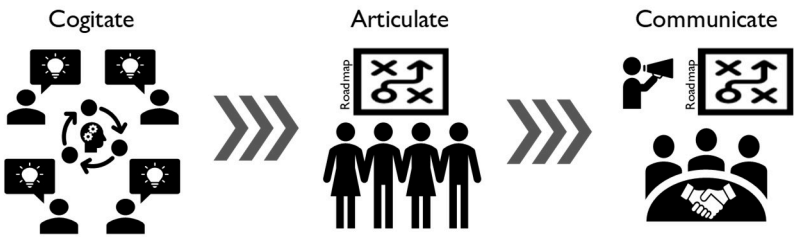

Figure 1 - People-centric perspective of roadmapping processes. Concept adapted from (Kerr et al., 2012)

The following section presents information regarding roadmapping software and how it addresses roadmapping activities and characteristics.

2.2 Software for roadmapping

Most of the core contributions concerning roadmapping occurred in the 1990s and 2000s, and afterwards, papers tend to focus on specific developments, customisations, and incremental improvements (Carvalho et al., 2013; Vatananan and Gerdsri, 2012). Despite this, there are still issues affecting roadmapping in practice, as reported by recent studies (Schimpf and Abele, 2019). Digital support for roadmapping seems to be an area where there is still a key gap.

DeGregorio (2000) reported the first study found in this research that emphasised the importance of software tools to support roadmapping. Building on Willyard and McClees (1987), DeGregorio discusses the application of software tools to support the integration of information and decisions in roadmapping at Motorola. A first generation of tools is cited, including a tool for decision-making (DecisionLink), focused on information management, and a tool for organising and visualising information (VisionMap). The author also indicated that a second generation of tools was under development.

Kostoff and Schaller (2001) included two main roadmapping approaches in their seminal roadmapping paper: expert-based and computer-based, which lead to different roadmapping results and roadmap structures. Expert-based roadmapping, which has evolved into the most used approach (Vatananan and Gerdsri, 2012), refers to gathering a group of experts together to develop roadmaps based on their knowledge and experience. Computer-based roadmapping considers the application of computational text analysis to collect and analyse information from databases. The authors claim that this type of roadmapping is more objective and does not suffer from personal or organisational limitations, constraints, and biases. At that time, authors reported that information databases and text analysis were in their embryonic stages, limiting their application.

Lupini (2002) compared three software tools with potential use for roadmapping: Microsoft Project; the US Office of Naval Research's Graphical Modelling System; and the enterprise roadmapping solution Geneva Vision Strategist, with its origins in Motorola - and then investigated components and requirements for roadmapping software based on a survey. First, this study reported that roadmapping software should comprise two main components: a graphical representation and a central database. Second, software requirements for each component were identified. For the graphical representation, categories of requirements are ease of creation, display format, and roadmap manipulation. The database requirements include defined data structure, remote working, and data control. Third, it addressed a pioneer roadmapping software – Vision Strategist – which is still in use in a later version as part of the Sopheon Accolade Platform for Innovation Management.

Richey and Grinnell (2004) described the implementation of roadmapping software in Motorola. They describe the Enterprise Roadmap Management System (ERMS) as providing a common process, software solution, and information architecture across the entire organisation. As part of the ERMS, the authors first describe the adoption of Vision Strategist software to support the creation of digital roadmaps, the same software addressed in Lupini (2002). They then present Vision Synergy, an add-on to Vision Strategist to involve individuals during roadmap creation and update. Although ERMS and Vision Strategist looked promising based on the authors' claims, roadmap creation using Vision Strategist/Synergy moved from a people-centric process to online interviews using forms (Richey and Grinnell, 2004).

Lee and Park (2005) and Lee et al. (2008a) described a software solution to support roadmap creation, dissemination and update. They highlighted the advantages of a web-based system, which can support

participants in accessing and retrieving information easily from different locations. In essence, the authors describe a software solution to help with designing, digitising, and managing roadmaps.

Lee et al. (2008b) described the application of text mining techniques to support information gathering when creating roadmaps, especially for collecting information from patent databases. This study used keyword-based mapping to complement information used to populate and integrate roadmap layers. Results suggest that collecting and organising information using quantitative techniques can enhance experts' judgment in the roadmapping process and lead to better roadmapping outcomes. This approach is aligned with the computer-based roadmapping reported by Kostoff and Schaller (2001).

A patent registered by Bushell et al. (2015), assigned to Boeing, describes a system to store roadmaps and automatically create new roadmaps based on the combination of the existing ones. The proposed system also includes a visualisation interface based on a web application. This system is aligned with the main components of roadmapping software suggested by Lupini (2002). However, it is closer to strategic planning than roadmapping software, since it encompasses several organisational elements and focuses on the evolution of business processes.

Abele, Schimpf and Spielberger (2018) and Schimpf and Abele (2019) have investigated roadmapping software and application characteristics in German companies, respectively. Fig.2 shows different types of information technologies used for roadmapping in the companies analysed. Only 10% used roadmapping-specific software, while Microsoft Office (Excel and PowerPoint) and project management software are the most frequently mentioned techniques. In addition, the comparison of software solutions described by Abele, Schimpf and Spielberger (2018) highlights that most current solutions focus on delivering a shared information database and a roadmap visual based on a Gantt-type chart structure.

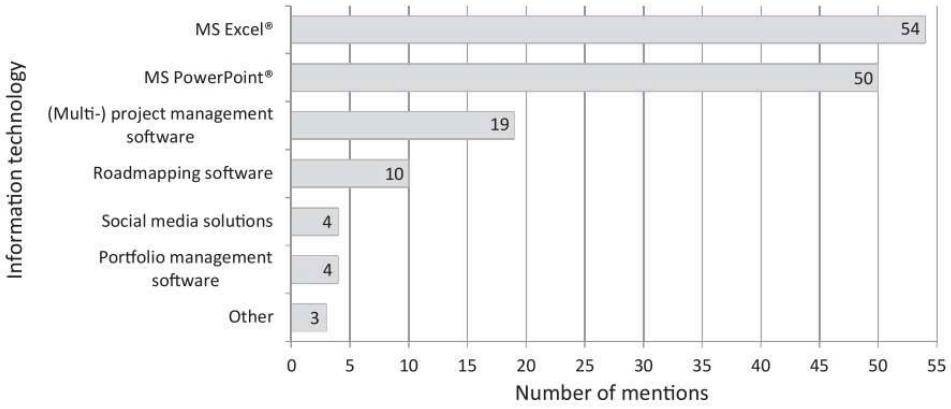

Figure 2 – Information technologies used in German companies for roadmapping. Source Schimpf and Abele (2019)

Ateetanan and Shirahada (2018) describe factors influencing the adoption of electronic roadmapping (e-roadmapping). The authors propose that digital technologies for electronic collaboration have reached a level of performance that enables the shift from face-to-face to electronic activities in roadmapping. Roadmapping experts were consulted through a questionnaire using a multicriteria method based on AHP (Analytic Hierarchy Process) to prioritise the most relevant factors for the adoption of e-roadmapping. Results show that social factors (leadership, organisational culture, and literacy - participants' control of the subject of analysis, roadmapping approach, and digital technologies) rather than technical factors are expected to have a greater influence on e-roadmapping. This study corroborates the relevance of people-centric characteristics for digital roadmapping but still offers no implementation verification.

Three main aspects of software functionality for roadmapping can be highlighted from the references reviewed:

1. Information management functions to collect, store, and retrieve roadmapping information.
2. Visualisation functions to present and manage roadmapping information through a Gantt-style framework (layers and timeline).
3. Decision support functions to analyse data from several sources (e.g., products, technologies, and markets) to enhance the information available for roadmapping activities.

Based on Abele, Schimpf and Spielberger (2018), current roadmapping software solutions address the first two functional aspects. Even though Lupini (2002) identified these aspects as important, the social factors highlighted by Ateetanan and Shirahada (2018) for the adoption of digital tools in roadmapping are missing in the available solutions.

The following section addresses digital tools aimed to support people-centric and collaborative workshop activities pertinent to the roadmapping approach.

2.3 Digitalisation of workshops for strategizing and design

According to the Cambridge Online Dictionary for Business, workshops are "*a meeting in which people learn about a subject by discussing it or doing activities relating to it*". In addition, from the strategy-as-practice perspective, workshops are viewed as "strategic episodes" (Hendry and Seidl, 2003; MacIntosh et al., 2010). In this sense, workshops, away-days, and similar activities are spatially and temporally disconnected from day-to-day work (Bourque and Johnson, 2008; Healey et al., 2015; Hodgkinson et al., 2006; Hodgkinson and Healey, 2008; Hydle, 2015; Johnson et al., 2010). Hence, "*Strategy workshops can be defined as specific events which take place outside the normal schedule of business meetings in an organisation and which focus explicitly on strategy*" (MacIntosh et al., 2010).

There are several sources of literature on the use of digital technology to support strategic episodes. Many studies from the 1980s onwards describe investigations of Group Support Systems (GSS) (de Vreede et al., 2003) and Group Decision Support Systems (GDSS) (DeSanctis and Gallupe, 1987; Nunamaker et al., 1989; Zigurs et al., 1989). These systems use computer support to structure activities to facilitate the sharing and use of information, often with the benefits of visibility of inputs across participants and anonymity of the providers of these inputs. Data manipulation and visualisation are also seen as key benefits of using such systems, which improve productivity, reducing anticipated person-hours to complete projects (Tyran et al., 1992). The most important contextual factors relating to the design of the GDSS were found to be the number of participants, their spatial proximity (co-located or dispersed), and the task they needed to accomplish (DeSanctis and Gallupe, 1987).

Dennis et al. (1988) provided a collation of studies undertaken at that time, using the terminology Electronic Meeting Systems to describe "*systems that use information technology to support the group work that occurs in meetings*". This included the computer hardware and software, audio and video technology, procedures, methodologies, facilitation, and applicable group data. The tasks included "*communication, planning, idea generation, problem-solving, issue discussion, negotiation, conflict resolution, systems analysis and design, and collaborative group activities such as document preparation and sharing*" (*ibid*, p.593). The majority of these tasks are also part of roadmapping workshops (Phaal et al., 2004). Computer-Supported Collaborative Work (CSCW) provides another rich source of information (Greeven and Williams, 2017; Koch et al., 2015; Neale et al., 2004; Schmidt and

Bannon, 2013) on digital support for collaborative activities seen to start in the 1990s, with a greater focus on the communication aspects compared with the task focus of the GSS and GDSS.

These collaboration activities continued into the 2000s when the Strategy-as-Practice community highlighted the need to have a research agenda including Information and Communication Technology (ICT) (Schreyer, 2000; Whittington, 2014). Key findings were that the digital systems used need to be matched to the task, the people, and the organisational context (Hüsig and Kohn, 2009). Digital process support tools can also be used to focus participants' attention in a collaborative activity on specific information (Mittleman et al., 2000).

For the specific idea generation activity, electronic brainstorming groups were found to be more productive and more satisfied with the interaction process than face-to-face groups (DeRosa et al., 2007). When considering participant numbers, it was found that large electronic brainstorming groups, where participants could see inputs from others anonymously, and build on these ideas, outperformed nominal groups where inputs from others could not be seen. Small nominal groups outperformed electronic brainstorming groups in productivity (DeRosa et al., 2007).

By the 2010s, digital technology was becoming more ubiquitous (Cascio and Montealegre, 2016). Recent experimental studies from the computer science and information systems disciplines focus on different digital devices and how these can work together to support specific objectives in collaborative contexts, often for sensemaking rather than explicitly strategizing (Homaeian et al., 2018; Wallace et al., 2013, 2011). When considering shared and personal devices, Wallace et al. (2013) found a positive correlation between the use of shared devices and group performance, and a negative correlation between the use of personal devices and group performance. Systems need to be easy to access (Rohrbeck et al., 2015) and easy to use (Cascio and Montealegre, 2016). Digital tools employed should be flexible – both in terms of the devices and the process support they offer to allow for multiple users and changing organisational requirements (Rohrbeck et al., 2015; Wallace et al., 2013). From a sociotechnical perspective, digitalisation within strategizing has shown potential for greater process transparency and inclusion of practitioners (Stieger et al., 2012; Vaara and Whittington, 2012).

In the same vein as the strategizing domain, design studies have investigated digital support as part of workshop activities. Gumienny et al. (2012) developed experiments to investigate the opportunities to transfer design work from physical to digital objects. Their results show that digital technologies have clear potential to support and enhance design work, especially in remote collaboration and information management and retrieval. However, the technical limitations these experiments faced hindered process performance and social adoption.

Recent studies suggest that the technical limitations faced by Gumienny et al. (2012) have been overcome. Jensen et al. (2018a, 2018b) present an extensive investigation concerning digital sticky notes in design activities. They find evidence that physical sticky notes promote better creation and posting of ideas, while digital sticky notes promote better idea organising and interaction. In addition, the authors report that both approaches can deliver similar brainstorming performance.

Lundqvist et al. (2018) report that the best results can be achieved by merging physical and digital tools. Their study follows five main workshop principles: 1) simple rules and no prerequisite skills; 2) mutual learning; 3) collaborative Ideation; 4) combinatorial creativity, and 5) externalisation of ideas. These principles show that digital tools can deliver beneficial results for ‘mutual learning’ and ‘collaborative ideation’. In contrast, physical tools seem to deliver better results for ‘simple rules and no prerequisite skills’ and ‘combinatorial creativity’. The ‘externalisation of ideas’ principle is best suited for a mix of partially physical and digital tools. Thus, this study claims that a combination of

digital and physical tools can improve processes and personal performance. This result is corroborated by research from Geyer et al. (2020) investigating the use of augmented digital sticky notes in design workshops.

Information collected from the literature has been used to support the research design to investigate the digitalisation of roadmapping workshops for this study. The following section presents the research method and phases.

3. Research Method

This exploratory research intends to develop knowledge to support roadmapping and, consequently, technology and innovation management. Roadmapping, like other management approaches and methods, has a solid link to industrial practice. Thus, research in roadmapping is often associated with empirical applications to develop knowledge that supports both theory building and empirical progress. This characteristic of roadmapping, although dealing with organisational and management sciences, makes it a domain of research aligned with design science.

The research characteristics of design and engineering sciences, which differs from natural and social sciences, are acknowledged in the literature (Bayazit, 2004). However, some research domains such as management seem to navigate through a variety of research approaches, creating a degree of dispute in management sciences (Hambrick, 2004; Hodgkinson and Starkey, 2012, 2011; Pandza and Thorpe, 2010; Willmott, 2012). This study does not enter into such debate, but in line with the characteristics of roadmapping, it follows a design and engineering science approach, in which, as proposed by (Popper, 1959), it uses proposals and tests in scientific discovery. This logic is aligned with Simon's (1996) "design of the artificial" concept, which is a core construct of design science research (van Aken, 2004).

Theory building in qualitative research is also a relevant topic in this study. Especially when research methods consider the investigation and development of empirical artefacts and processes. Eisenhardt's work is essential for this topic (Eisenhardt, 2021, 1989). Theory building is an evolving process that learns and adapts through theoretical and empirical cycles. This study also follows this research approach.

Then, this study links design science research (Simon, 1996) and theory building (Eisenhardt, 1989) through an inductive-based approach. This is a characteristic inherent of this study, which conducts digital roadmapping workshops to gather data and insights to support the progress in practice and theory of roadmapping and strategic workshops using digital technologies. A deductive-based approach, using the extant literature, would be another route to address this topic (Hodgkinson and Healey, 2008).

Based on the logic of design science research (Simon, 1996) and qualitative theory building (Eisenhardt, 1989), this study proposed three research phases to investigate the research question: 'To what extent and in what ways can replacing physical tools with digital ones enhance roadmapping workshops?' Each research phase was designed to simulate tasks of digital roadmapping workshops and support progressive learning. The development of simulated workshops was required since digital tools for roadmapping are not common industry practice.

The first research phase introduced digital tools into a roadmapping workshop, addressing their feasibility in terms of usefulness and ease of use. The second phase aimed to uncover critical differences between the usability of physical and digital tools in roadmapping workshop tasks. These

two phases were video-recorded, with participants' assessments collected using semi-structured questionnaires, prepared using the usability framework proposed by Davis (1989) - presented in the appendix. The third phase increased the number of workshop participants to investigate the usability of digital tools and workshop experience. This phase was conducted as part of an industrial consortium event, and information was collected from researchers' observations and participants' oral feedback. Data collection in this last phase was made using researchers' notes and pictures and took place throughout the workshop. A focused feedback session was included at the end of the workshop agenda to gather in-depth insights from participants.

Data collection in the workshops was predominantly qualitative, despite the application of questionnaires with scales in research phases one and two. These questionnaires were used to supplement the other data collection instruments (recordings, roadmap data and researchers' observations), capturing participant feedback. More information regarding the questionnaires used is presented in the research findings and the appendix.

The three research phases focused on replicating, as closely as possible, the core physical tools used in strategic roadmapping workshops (paper chart, sticky notes, and stickers) with digital tools (interactive display, personal computer, and whiteboard software) for comparison. Simulated roadmapping themes with predefined information were prepared for the workshops, focusing the participants' attention on their digital roadmapping experience.

All phases used as material a high-performance commercial 75" 4K Interactive Display with InGlass™ technology, and a web-based whiteboard software solution in which a digital roadmap template, sticky notes, and stickers were available as the digital tools. Participants used personal computers to interact with the shared digital working space.

This study aimed to gather a general perspective on digital roadmapping, without restricting participant profiles, in the same way as regular roadmapping workshops would involve a range of participant profiles. Therefore, although described at the beginning of each research phase, participants' age and gender are not controlled in this study.

The lead author acted as the roadmapping and digital facilitator for the workshops. A 'self-facilitating' approach was adopted, i.e., the facilitator provided participants with templates, main steps and expected results. His primary purpose was to support participants to follow the proposed digital roadmapping activities and agenda, but with minimum intervention. When required, he assisted participants with the digital technologies, ensuring they could progress jointly throughout the roadmapping stages. A second facilitator was only used in the second research phase to provide additional support, ensuring that the two groups were promptly assisted if needed. In addition, to reduce potential facilitators' biases, the participants provided their feedback regarding the digital workshop. In this sense, they also acted as observers of the phenomenon in analysis, mitigating potential facilitators' biases (Rowland and Spaniol, 2021).

3.1 Phase 1 – Feasibility of using digital tools

This phase involved a first workshop involving five participants with an average age of 39 years (standard deviation of 10 years), four men and one woman. It was organised as a product-technology roadmapping workshop lasting 2.5 hours – see Table 1 for agenda.

Table 1 – Workshop Agenda in Phase 1

Time	Activity
30 min	Introduction to workshop and digital tools

20 min	Coffee break
80 min	Roadmap development
20 min	Feedback discussion and questionnaire

A product-technology template had been pre-loaded into the whiteboard software to guide participants. This template incorporated layers representing market (why?), product (what?) and technology/resources (how?), with a timeline of 30 years (incorporating short, medium, and long term). The subject of analysis involved a new product line for a car manufacturer, adapted from examples used in training and prior research.

For the roadmap development, participants received a link to access the shared digital workspace containing the roadmap template. Then, they filled in information about the subject using digital sticky notes individually on their laptops, as shown in Fig. 3. Participants could also fill in information directly on the interactive display using a wireless keyboard, the on-screen digital keyboard, or a screen pencil with a handwriting recognition function. They were instructed to fill in each layer separately and start positioning their digital sticky notes on the timeline during the process. The workshop participants received predefined information with guidance on where to include it in the roadmap, thereby helping them fill in roadmap layers.

Figure 3 – Completing roadmap layers in the product-technology digital roadmapping

After they finished completing roadmap layers, participants were asked to create narratives (organise and link information) using the information on the digital roadmap template. They were asked to work as a group using the interactive display for this task, as shown in Fig. 4. The facilitator let the team self-manage their activity with the interactive display and only provided support if asked.

Figure 4 - Creating narratives in the product-technology digital roadmapping

At the conclusion of the Phase 1 workshop the participants completed the assessment form and discussed the advantages and disadvantages of using the digital roadmapping approach as a group.

3.2 Phase 2 – Comparing physical and digital tools' usability

This phase involved workshops that compared digital and physical tools' usability for capturing ideas, charting these into a roadmap narrative and sharing that narrative with others for feedback. Participants were invited from the student and industrial community and had a range of experience in roadmapping. Two workshops were performed in this phase, one involving seven participants with an average age of 33 years (standard deviation of 11 years), five men and two women; and another involving six participants with an average age of 34 years (standard deviation of 13 years), four men and two women.

The workshops were organised as 2-hour activities (see Table 2 for agenda), following a gaming approach in which two groups competed to create the 'best' roadmaps. Initially, the facilitator introduced the activities to participants and allocated the two groups, i.e., 3-4 participants per group. Then the two groups undertook their initial roadmap development and sharing – game round 1. Everyone scored game 1 before game round 2 – developing and sharing the second roadmap and scoring. At the end of the game, points were collated, and feedback was gathered using a feedback form (see appendix) and discussion.

Table 2 –Workshop Agenda in Phase 2

Time	Activity
10 min	Introduction to workshop
45 min	Game round 1 – Group A digital, Group B paper
10 min	Coffee break and collation of points?
45 min	Game round 2 – Group B digital, Group A paper
10 min	Scoring, feedback discussion and questionnaire
30 min	Introduction to workshop and digital tools

20 min	Coffee break
80 min	Roadmapping development
20 min	Feedback discussion and questionnaire

Winners were defined based on three criteria: roadmap content, roadmap narratives and roadmap presentation. The assessment involved all groups and facilitators. The room layout for the game is shown in Fig. 5.

Figure 5 – Room layout for the roadmapping game used for the strategic digital roadmapping workshop

Four themes were available for playing: smart cities, financial revolution, digital healthcare, and sustainable manufacturing. For game round 1, each group was assigned to a theme and a physical or digital set of tools. Then, for the second round, groups switched tools and worked with the two new themes. An introductory abstract and a set of cards including predefined information were available for each theme. Groups were asked to use the information provided but could also complement this with their ideas as required.

Groups were supported by two roadmapping facilitators (authors) to guarantee they could follow the three main round steps: 1) populating the roadmap template, 2) connecting items and creating narratives, and 3) presenting the roadmap.

The physical roadmapping approach used paper charts, sticky notes, stickers and pens. In contrast, the digital approach used personal computers, a 75" interactive display and a digital whiteboard software solution. The same roadmap template was adopted for both, following basic roadmap layers and a timeline (Phaal et al., 2004). Fig. 6 shows participants engaging with the physical and digital tools in phase 2.

Figure 6 – Roadmapping game in Phase 2

For each workshop in this second research phase, participants completed a form in which they considered the game itself an instrument to help with roadmapping and their experience with the digitalisation of roadmapping. In addition, they were asked about which approach, paper or digital, they would prefer for roadmapping.

3.3 Phase 3 – Digital tools in large group roadmapping

A new workshop using digital tools, illustrated in Fig 7, was conducted in this third research phase. It aimed to investigate a large group capturing and sharing ideas on a roadmap architecture. The thirteen participants were self-selected from an industrial consortium. They represented a heterogenous selection of industry practitioners, often found in a sector-level S-Plan roadmapping workshop (Phaal et al., 2007). At the time of the workshop, they had an average age of 44 years (standard deviation of 5 years), being 11 men and two women.

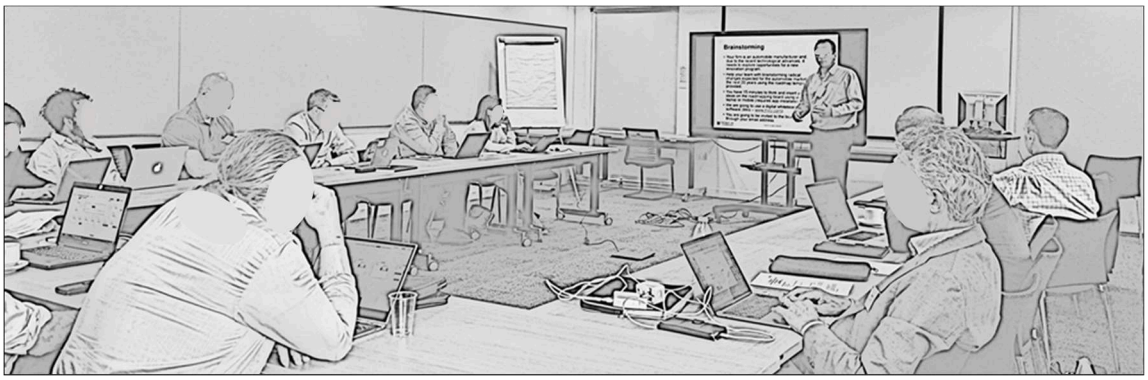

Figure 7 – Large group roadmapping workshop in Phase 3

This workshop was organised as a 2-hour activity (see Table 3 for agenda) and followed the 'landscaping' part of strategic roadmapping (Phaal et al., 2007). The second part of strategic roadmapping, which involves splitting participants into small groups, was not conducted as the dynamic of digital roadmapping with small groups had already been addressed in the first two research phases. Oral feedback was captured at the end of the workshop.

Table 3 – Workshop Agenda Phase 3

Time	Activity
10 min	Introduction to workshop and getting participants setup
15 min	Subject background presentation
25 min	Individual brainstorm activity on own computer, accessing shared whiteboard
45 min	Presenting brainstormed ideas and populating the digital landscape
15 min	Prioritising ideas
10 min	Feedback discussion

The workshop started with introductions and ensuring participants had digital access. The landscaping activity started with a presentation about the theme to be addressed. Next, participants were asked to brainstorm ideas for the roadmap. Each participant was given access to the standard roadmap architecture template on the shared digital whiteboard, with the ability to interact through their personal computers. They were also assigned to a specific digital desk (reserved individual space) that had been previously set up on the digital workspace, as shown in Fig. 8. The digital whiteboard was also visible on the interactive display at the front of the room, as shown in Fig. 7.

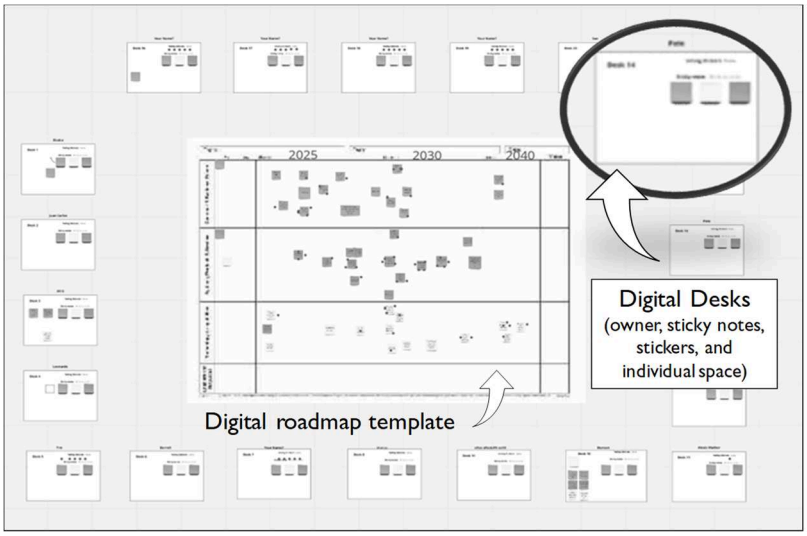

Figure 8 – Digital workspace created for the workshop in Phase 3.

After generating and capturing their ideas with digital sticky notes, they were invited to go to the interactive display and present them. In addition, they needed to move their notes from their digital desk to the desired positions on the digital roadmap architecture template. The participants' interaction with the display is shown in Fig. 9. This activity took about 45 minutes, as each participant was given about three minutes to present. Finally, participants were asked to prioritise ideas in the roadmap architecture using digital sticker votes, also available on their digital desks. As a result, the most important ideas were highlighted on the roadmap.

Figure 9 – Participants using the display to present and place their ideas on the digital roadmap.

4. Research findings

Analysis of data collected from the three research phases provides findings regarding the application of digital tools for workshops and their impact on roadmapping. The following sections present findings for each phase.

4.1 Phase 1 – Feasibility of using digital tools

Table 4 shows the average data collected from the five participants in phase 1 using the evaluation form, which adopts a seven-point Likert scale (from +5 for extremely likely, to -5 for extremely unlikely), consisting of two main parts: usefulness and ease of use of digital tools. There was also an opportunity for participants to include further comments on the form and through group discussion.

The average score for usefulness is 1.6, indicating a slightly positive perspective regarding the utility of digital tools for roadmapping. The lowest rating (0.6) was for making roadmapping easier (reducing complexity), while the highest rating was for the general comment of finding digital tools useful (2.6). So, although participants perceive the digital tools as useful for roadmapping, they also report in comments and discussion uncertainties of how it could affect the roadmapping process.

The average score for ease of use is 2.9, indicating a stronger positive perspective. These results suggest that using digital tools is not a barrier to digital roadmapping. The digital tools employed for this phase were simple and focused on small tasks. In addition, technologies such as the touch-screen interface are mature and already used by participants as part of their everyday activities, reducing barriers.

Table 4 - Evaluation of the usability of digital tools in phase 1

Part 1 – Usefulness of Digital Tools for Roadmapping	**Score (-5 to +5)**
1. Using these digital tools would enable me to accomplish roadmapping more quickly (time-saving)	1.6
2. Using these digital tools would improve my roadmapping performance (capabilities)	1.0
3. Using these digital tools would improve my roadmapping productivity (processing skills)	2.0
4. Using these digital tools would enhance my roadmapping effectiveness (goals achievement)	1.8
5. Using these digital tools would make roadmapping easier (reduce complexity)	0.6
6. I would find these digital tools useful for roadmapping	2.6
Average Score	1.6
Part 2 - Ease of Use of Digital Tools for Roadmapping	**Average Score**
1. Learning to operate these digital tools would be easy for me	2.6
2. I would find it easy to get these digital tools to do what I want to do	2.6
3. My interaction with these digital tools would be clear and understandable	3.4
4. I would find these digital tools to be flexible to interact with	2.8
5. It would be easy for me to become skilful at using these digital tools	3.0
Average Score	2.9

From phase 1 observation, participants were able to follow a basic roadmapping process using the digital tools supplied, and no critical issue or concern was found during the workshop, leading to the conclusion that it is feasible to use digital tools in roadmapping workshop activities

Since basic activities were easily accomplished, participants wondered about potential improvements using digital tools. They asked many questions in the group discussion about the possibilities of the whiteboard software, specifically, information management, such as grouping, merging and exporting information in digital sticky notes. Another point raised concerned how information in the digital whiteboard could be used and shared after the workshop, aiming to improve reviewing and reporting activities. Finally, virtual collaboration was also mentioned since it is a clear opportunity if moving to a digital approach.

4.2 Phase 2 – Comparing physical and digital tools' usability

In phase 2, the evaluation form was refined to improve participants' understanding of the criteria. The Likert scale was reduced to 5 points, from +3 (strongly agree) to -3 (strongly disagree), to differentiate between participants' opinions more clearly. Again, participants had the opportunity to contribute comments, both on the form and in plenary group reflection. Since the first phase supported the feasibility of using digital tools for roadmapping, this second phase focused on collecting data on usability, leading to a comparison between digital and physical tools. Table 5 shows the average feedback data collected from the 13 participants who participated in the roadmapping game.

Table 5 - Evaluation of the usability of digital tools in Phase 2

Criteria of Assessment	**Average Score (-3 to +3)**
1. I found easy to learn the digital tools provided	2.1
2. I was able to use the digital tools to do what I wanted	1.7
3. My interaction with the digital tools was straightforward	1.6
4. The digital tools were flexible to help me with my game tasks	1.8
5. I would prefer using digital rather than paper tools for roadmapping	1.5

All the scores in Table 5 indicate that participants agree to strongly agree that the digital tools are easy to use for roadmapping activities. Reflecting on the results for the five criteria in Table 5 together with observations and qualitative feedback:

1. **I found easy to learn the digital tools provided (average score 2.1):** although new to some participants, the digital tools employed (interactive display, digital whiteboard, digital sticky notes, and digital stickers) were simple to use. Initially, some participants were wary of the interactive display since they needed to feel the touch sensitivity and response and learn how to use the functions. Still, they understood their use very quickly and overcame this limitation.
2. **I was able to use the digital tools to do what I wanted (average score 1.7):** according to participant feedback, some prefer writing on paper sticky notes. However, they reported that the digital approach was easier when they needed to manage sticky notes on the board (move and organise). In addition, the establishment of connections to show narratives was more effective and efficient on the digital board. Digital links were more flexible to work with than drawing or using sticky arrows on the paper chart. Another advantage of the digital tools was that, during the presentation, the digital board allowed zooming in and out to clarify the information and narrative to the audience.
3. **My interaction with the digital tools was straightforward (average score 1.6):** the interaction with digital tools was organised to support the digital workshop. In this context, participants had few issues with writing in digital sticky notes (using their laptops or the interactive display) and linking items in the whiteboard software. When needed, modest support from the facilitator was enough to overcome issues. The novelty of the interactivity is still a barrier for some people, who will need to be introduced to the equipment with care.
4. **The digital tools were flexible to help me with my game tasks (average score 1.8):** the digital tools were designed to facilitate the same process and interaction as the physical tools. Pads of digital sticky notes and stickers were created and made available beside the digital roadmap template on the digital whiteboard, like the physical process. Many participants mentioned that

the digital tools were more flexible than the physical tools to manage information and narrative creation.

5. **I would prefer using digital rather than paper tools for roadmapping (average score 1.5):** this positive score indicates participants would prefer digital tools for roadmapping, as some advantages such as manipulation have been noted, although paper was preferred for some activities (ideation), which perhaps kept the score lower than strongly agree.

Phase 2, therefore, showed that for roadmapping workshop tasks such as capturing ideas, charting these into a roadmap narrative and sharing that narrative with others for feedback, digital tools were usable and, in some aspects, preferable to paper tools.

In addition to evaluating the digital tools, participants were asked to assess the digital roadmapping game. Scores in Table 6 indicate that the roadmapping game fulfilled participants' expectations and, therefore, supported the workshop with digital tools.

Table 6 - Participants' feedback on digital roadmapping game.

Criteria of Assessment	**Average Score (-3 to +3)**
1. The game instructions were clear to guide me through it	1.92
2. The game material was easy to use	1.92
3. The time provided was appropriate for achieving the goals	1.54
4. The game help me with learning the roadmapping approach	1.15
5. I would recommend the game to other people	1.85

4.3 Phase 3 – Digital tools in large group roadmapping

In phase 3, the participants' feedback was positive regarding their interest in using digital tools for landscaping. They found it helpful to use a single screen to collect all the inputs together, and they could see potential for digitalisation for ease of data manipulation after a workshop. Although the workshop conducted was the first contact with these digital tools for most of them, adoption of the tools was easy. Some participants had multiple personal computers and experimented to find which one they were most comfortable using to achieve the task. A few participants demonstrated proficiency with the tools, adjusting the font size and sticky notes to enable visibility of their presentation across the whole room. The main shortcomings faced were the digital workshop design for a large group.

The first issue was the visibility provided by a 75" (165 x 93cm) display to a group of 13 participants. Participants could see content clearly on their computers by zooming in on an area, but this loses the holistic overview of the landscape and, therefore, the location of the content in terms of the roadmap architecture. For a large group, even when using a paper template, a much larger size is required to allow participants to see the considerable volume of information collected on a landscape. From the authors' experience, a minimum size of four A0 equivalent template would be recommended (168 x 238cm), similar in scale to four 75" displays assembled side-by-side.

Another issue arose when participants moved items from their digital desks to the roadmap template. Since they were using computers with small screens (laptops or tablets with a maximum screen size of 15''), and the digital workspace had been designed to include many digital desks and a large roadmap template, selecting and moving items on the digital whiteboard became a problem. They

needed to cross multiple screen sizes to reach the desired place in the digital roadmap. Moreover, if they zoomed out, their sticky notes were too small to select. Therefore, the size of digital desks and roadmap template displays (individual or group devices) need to be designed to improve usability in future applications.

Finally, a few participants had issues connecting with the shared digital whiteboard and computer performance. Since participants were asked to bring their computers, there was no control of the equipment used. Further analysis of minimum hardware requirements is needed. For example, a digital kit could be made available to participants to guarantee performance. In addition, this could help participants to focus on the activity. It was noted that there were frequent side-activities when participants were working with their laptops.

5. Discussion

This study investigated the potential to use digital tools in roadmapping workshops - an important part of roadmapping processes – which has little support from current solutions. Literature shows that although roadmapping software has addressed information management and visualisation, functionalities related to people-centric and collaborative characteristics lack support. To address this gap, the following research question was proposed: 'To what extent and in what ways can replacing physical tools with digital ones enhance roadmapping workshops?' This section discusses the impact of digital tools in different stages of roadmapping processes (cogitate, articulate, and communicate) and how group size can affect results.

5.1 Digitally-supported roadmapping processes

Two main digital tools were employed to support the workshops conducted in this study – a large interactive display (75") and a whiteboard software solution. In addition, participants used their computers to insert and edit information on the digital roadmap template, shared through internet connectivity. The application of these tools is analysed based on the three main roadmapping stages described by Kerr et al. (2012): cogitate, articulate, and communicate.

5.1.1 Cogitate with digital tools

The cogitate stage refers to brainstorming activities conducted during the first stage of roadmapping. Predefined information was used to boost brainstorming in workshops 1 and 2. This practice is already used in roadmapping workshops, where participants are asked for complementary ideas to build on prepopulated information. Only phase 3, which focused on landscaping, included a brainstorming session with no predefined content, as may happen with a larger sector-level roadmapping activity.

The cogitate stage starts with individual engagement and is followed by group discussion, enhancing individual idea generation. At the beginning of all the digital workshops conducted, the facilitator briefly introduced the digital workspace and functions required during the workshop, i.e., connecting to the shared board, and creating, writing on, and moving sticky notes on the digital board.

Participants focused more on inputting their ideas and information digitally than group discussion during the cogitate stage in the workshops. It is not clear if this was due to the novelty of the digital tools employed, the transcription of predefined information or an artefact of the simulated change from physical to digital roadmapping. In phase 2, participants initially discussed who would transcribe the re-defined content before working individually on the task, using either set of tools.

In phase 1, since participants were all using the same shared workspace, issues arose when participants tried to create and pick a digital sticky note. Sometimes, two participants tried to use the same digital sticky note, unaware of others' interaction with the sticky note. This issue was solved in the subsequent workshops by: 1) creating, before workshops, digital sticky note pads, which removed the need to create sticky-notes, i.e. participants could write and move them; and 2) directing people to reserved digital spaces in phase 3, which gave them a sense of personal space to work without worrying about invading others` ideas and picking others` sticky-notes.

Participants accomplished their cogitate tasks in roadmapping with the digital tools supplied. However, in phase 2, they preferred physical tools to support brainstorming, helping participants focus on the idea generation. Also, the additional concentration needed to perform the digital task may lead to less natural interaction during brainstorming. This result is confirmed by studies addressing digital workshops (Gumienny et al., 2012; Jensen et al., 2018a, 2018b). Facilitators should pay special attention to promoting group interaction during digital cogitate sessions in roadmapping, ensuring that participants can access each other's content to build on (DeRosa et al., 2007). However, participants should not inadvertently edit and move contents, perhaps providing a hybrid tool approach to reduce the cognitive load (Lundqvist et al., 2018).

5.1.2 Articulate with digital tools

At the end of the cogitate stage, participants individually presented their ideas to the group. In all the phases, people read their ideas and showed where they placed them in the digital roadmap template – starting the articulation stage of the psychosocial framework as proposed by Kerr et al. (2012).

Phase 3 showed that some participants were able to effectively use the digital functionality to make their content visible across the room when presenting their ideas to other participants. While there were some challenges with moving the content to the desired landscape area, all participants could view the placement of the ideas being put forward on the large display or their devices. This visibility of content and placement is not always feasible in large workshop situations using paper-based tools.

The next activity involved reviewing and organising ideas. This activity helps participants understand the context and meaning created and how they can approach it to create strategic narratives for the roadmapping theme. Phase 2 participant feedback indicates that reviewing and organising ideas in the digital format was easier and was thought to provide a better result.

Then, the prioritisation activity was implemented through digital stickers to replicate the physical stickers as closely as possible. In Phase 2, participants had a shared digital screen to place votes in the same manner as a paper-based workshop – so participants had limited space to see the same information. As a result, some participants may miss parts and perform a less effective choice. In phase 3, most participants used their personal computers to scan across the landscape during the prioritisation activity and so participants could easily and simultaneously individually explore ideas in the roadmap. This seems to offer a significant advantage in terms of effectiveness for prioritisation and efficiency, as facilitators need to reserve more time to allow minimum access for every participant in a physical workshop. Other advantages of digital prioritisation are the potential to remove bias because everyone can vote simultaneously. Since a voting function is available in the whiteboard software, these votes can be implemented without visibility to others and then tallied and displayed much more quickly.

Finally, for creating strategic narratives, participants in phase 2 stated that it is easier to create links and position notes in the digital format, which enables the design of a better narrative flow through

the roadmap layers and timeline. This result is also corroborated by published studies of digital workshops (Gumienny et al., 2012; Jensen et al., 2018a, 2018b).

5.1.3 Communication with digital tools

The communication stage was primarily addressed in phase 2, where each group was required to share their roadmap with the other group in the session. Although it is acknowledged that the majority of communication for roadmapping typically takes place after a workshop session, the findings suggest that digital tools can provide substantial support to improve communication in roadmapping. After a strategic narrative is created, a critical activity is its presentation to all participants. However, since the elected presenter needs to follow the narrative in the roadmap, listeners can hear the explanation but not necessarily see the visual narrative due to their distance from the roadmap chart. In the digital format, the presenter can zoom in and out to explain the narrative, giving a more in-depth explanation and a better sense of position in the roadmap. Fig. 10 shows a presenter zooming in and out to help with explaining the narrative and focusing participant attention (Mittleman et al., 2000).

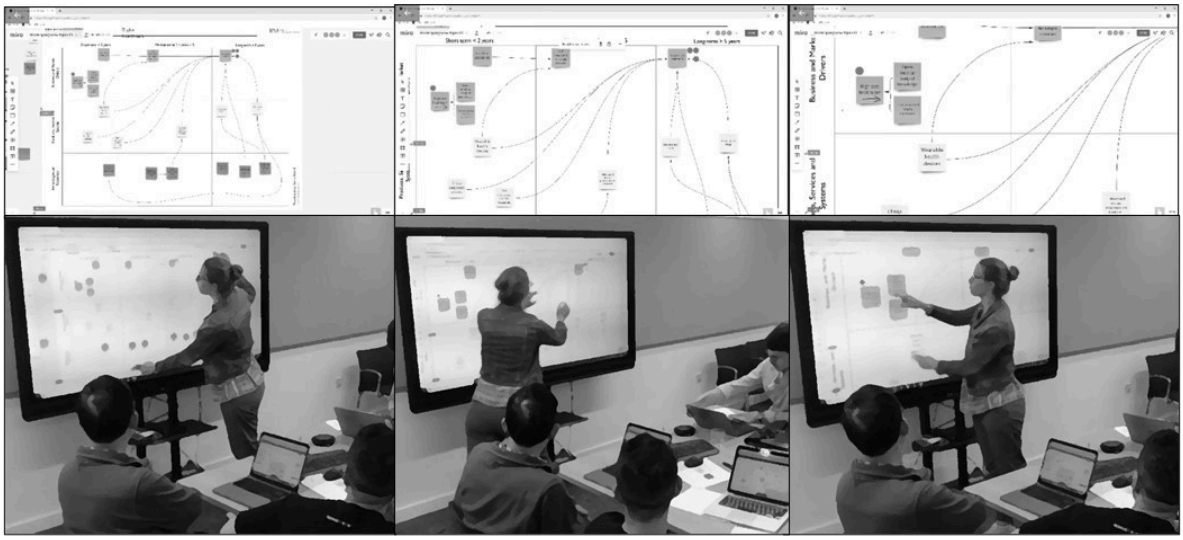

Figure 10 – Presenter zooming in and out to help with explaining a roadmapping narrative

Since the roadmap and its information created during the workshop are digital, stakeholders can access results immediately after the workshop. In addition, tasks related to the transcription of workshop results are reduced, helping with facilitators' effort in post-workshop activities. Although insights concerning communication seem potentially supportive of digital tools, further investigation is required to clarify the impact on post-workshop roadmapping activities.

Finally, the impact of digital tools on the communication between participants and facilitators was not addressed in this study since the workshops proposed focused on other roadmapping constructs. This type of communication can be relevant for roadmapping once facilitators are required to drive participants' work, particularly for large groups. This point can be investigated in future studies.

5.2 Group size in digital roadmapping

Roadmapping workshop processes for small and large groups are different in terms of people involvement, design, and facilitation. As a result, and as noted by previous digitally supported strategizing studies (Dennis et al., 1988; DeSanctis and Gallupe, 1987), group size is also expected to impact digital roadmapping. The facilitation of small groups tends to be less critical in roadmapping

when compared to large groups. In large groups, precise guidelines are required to keep time, guarantee alignment to expected results, and support democratic and consensual decisions. In addition, large groups also mean more information and working space, both in terms of room and template space (Gerdsri et al., 2009; Phaal et al., 2007, 2004).

The first two phases involved small groups (5 or fewer participants), while the third phase involved a large group (more than 10 participants). For the small groups, no relevant constraint was noticed in the workshops. However, some shortcomings were found in the large group workshop, as discussed in section 4.3. The introduction of digital tools represents an additional element to manage as part of roadmapping applications. In this sense, while participants are not entirely familiar with digital tools, they are expected to need support in large or small groups. However, large groups have a higher probability of unexpected digital issues. Therefore, facilitators should plan for extra time in digital workshops for digital support, with backup options in terms of equipment (e.g., laptop, displays) and services (e.g., internet, software) or the preparation of pre-tested digital kits to support participants in workshops.

Another relevant point for digital roadmapping in large groups is an investment in infrastructure. Large groups will require more interactive displays, software licenses, connection bandwidth and personal computers. Thus, roadmapping workshops that could be prepared at a relatively low cost (paper sticky notes and paper templates) may involve high costs if the equipment is not available in the organisation or venue where the workshop is organised. Among the required materials, interactive displays seem to be the core constraint because of cost and difficult transportation. However, interactive displays may become widely available shortly, and other visualisation tools could be employed to deliver a similar experience.

6. Conclusions

6.1 Theoretical Implications

Based on the findings from these phases, it can be stated that digital tools have significant potential to replace physical tools in roadmapping workshops, offering possible advantages to support critical tasks. Prioritisation, communication, and data manipulation were positively impacted in the digital workshops conducted. This result aligns with other studies that investigated digital tools for workshops (Gumienny et al., 2012; Jensen et al., 2018b). While the psychosocial framework (Kerr et al., 2012), which addresses cognitive and social aspects of roadmapping activities, supported the constructs explored in this study, it points to a need to investigate the sociotechnical implications of digital tools in roadmapping. The bodies of literature investigating the ritualisation of strategy workshops (Bourque and Johnson, 2008) and cognitive mapping (Hodgkinson et al., 2004) can also provide insights to explore this sociotechnical roadmapping perspective.

Prioritisation, communication, and data manipulation as part of workshops are activities also performed by other technology and innovation management processes, particularly regarding digital collaboration, a digitisation line highlighted by (Farrington and Alizadeh, 2017). Therefore, the findings of this study, although analysed for roadmapping, may serve as a starting point for other studies addressing digitalisation in technology and innovation management.

The constructs analysed in this study regarding the digitalisation of roadmapping workshops focused on activities performed within workshops and analysed the transition from physical to digital tools. Thus, the impact of digital tools on the implementation of roadmapping strategies and plans in organisations was not addressed. Despite this, the introduction of digital tools, as discussed in section

5.1.3 about communication, indicates easier retrieval of information needed to understand the developed roadmapping strategies and plans. This point could help with the future implementation of results into organisations. In this sense, the impact of digital tools on the implementation of workshop results is still unclear and could be further explored to support the “effectivity paradox” discussed in the literature on strategy workshops (Healey et al., 2015; MacIntosh et al., 2010).

6.2 Empirical implications

This study presented digital roadmapping applications through three research phases: feasibility of using digital tools, comparing physical and digital tools, and digital tools in large group roadmapping. These phases covered different roadmapping aspects and how they could be addressed with digital technologies, thus serving as an example for practitioners looking to engage with digital technologies for roadmapping. Thus, we would like to highlight three core implications for practice.

Firstly, the introduction of interactive displays and digital whiteboards has shown great potential regarding the digitization of roadmapping workshops. The risks of adopting digital technologies that could lead to time and focus loss on workshops, caused by technical issues or participants' adoption, seem to have decreased considerably with current technological progress. Thus, this study has shown that the trade-off between the risks and benefits of adopting digital technologies in co-located roadmapping workshops has changed, justifying practitioners to consider digital.

Secondly, the adoption of digital technologies indicated relevant and positive changes in critical roadmapping activities. A core contribution is seen regarding the co-located digital roadmapping approach's support to strategic formulation. The flexibility of digital whiteboards allows easier and faster experimentation of strategic narratives in the roadmap, adding further value to roadmapping participants.

Thirdly, data and information created in the roadmapping process become digital. This fact opens new and unexplored opportunities to add value. Digital data and information reduce effort and time between the workshops and the implementation of results, i.e., help participants to leave workshops with results for effective implementation. Moreover, data and digital information are easily stored, shared and updated, supporting a more live approach to roadmapping.

6.3 Limitations and future research

The results presented are part of simulated digital roadmapping activities. Therefore, there are generalisation limitations. Simulated roadmapping activities can miss relevant factors of real roadmapping cases. The digital workshops embraced only the workshop stage of roadmapping and did not consider pre- and post-workshops activities, which can provide further insights concerning digital roadmapping. The presence of a facilitator was intended to ensure proper roadmapping development. Nevertheless, it may have created biases in the results obtained.

Regarding the research method, this study followed an inductive approach based on design science research (Simon, 1996) and theory building (Eisenhardt, 1989) to define its research phases. As a result, it explores and gathers initial insights to support further development of digital roadmapping. Kerr et al.’s (2012) framework was used to analyse the research findings, but it was not considered in the data collection, leading to a limited consideration of the framework elements. In addition, the instruments used to collect data in workshops changed over the research process, hindering cross-comparison between digital roadmapping applications in different research phases.

Roadmapping is flexible in scope, goals, activities, and tools. Configurations tested in this study cover only a small sample of the potential roadmapping configurations. In addition, this study adopted three main digital tools to deliver digital and co-located roadmapping workshops (interactive display, personal computer, and whiteboard software). They are elements of the workshop design investigated in this study. Other digital tools and combinations to design a digital workshop can be investigated by other studies, providing further evidence for digital roadmapping. Finally, this research was conducted before the Covid-19 pandemic, and the inclusion of design elements supporting remote and asynchronous collaboration is expected for future developments.

This study also suggests for future research:

- Investigation of digital tools in industrial roadmapping applications.
- Investigation of the impact of digital tools on participant engagement in roadmapping.
- Investigation of the impact of digital tools on the communication stage of roadmapping.
- Investigation of other digital tools that could provide further digital interaction among participants, such as virtual and augmented reality.
- Investigation of digital tools in remote and asynchronous roadmapping applications.
- Development of performance metrics for roadmapping, using Kerr et al.'s (2012) framework and other studies, to include processual and people-centric characteristics, which could support a precise comparison between physical and digital roadmapping value offers.

6.4 Final consideration

This study has addressed the impact of adopting digital tools on roadmapping workshops. To this end, digital co-located roadmapping workshops were conducted in three research phases, covering the feasibility of using digital tools, comparing the usability of physical and digital tools, and analysing digital tools in large groups. The digital workshops provided an entirely new experience to participants and presented new and unexplored opportunities to improve roadmapping theory and practice.

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8. Appendix

8.1 Evaluation criteria used for research phase 1

Please, mark your answers below using the provided scores.

PART 1 – USEFULNESS OF THE DIGITAL TOOLS Please select the responses that best describe your opinion about the usefulness of the digital tools used at this workshop	Extremely Likely	Quite Likely	Slightly Likely	Neither	Slightly Unlikely	Quite Unlikely	Extremely Unlikely
1. Using these digital tools would enable me to accomplish roadmapping more quickly (time saving)	+5	+3	+1	0	-1	-3	-5
2. Using these digital tools would improve my roadmapping performance (capabilities)	+5	+3	+1	0	-1	-3	-5
3. Using these digital tools would improve my roadmapping productivity (processing skills)	+5	+3	+1	0	-1	-3	-5
4. Using these digital tools would enhance my roadmapping effectiveness (goals achievement)	+5	+3	+1	0	-1	-3	-5
5. Using these digital tools would make roadmapping easier (reduce complexity)	+5	+3	+1	0	-1	-3	-5
6. I would find these digital tools useful for roadmapping	+5	+3	+1	0	-1	-3	-5

PART 2 – EASE OF USE OF THE DIGITAL TOOLS Please select the responses that best describe your opinion about the ease of use of the digital tools used at this workshop	Extremely Likely	Quite Likely	Slightly Likely	Neither	Slightly Unlikely	Quite Unlikely	Extremely Unlikely
1. Learning to operate these digital tools would be easy for me	+5	+3	+1	0	-1	-3	-5
2. I would find it easy to get these digital tools to do what I want to do	+5	+3	+1	0	-1	-3	-5
3. My interaction with these digital tools would be clear and understandable	+5	+3	+1	0	-1	-3	-5
4. I would find these digital tools to be flexible to interact with	+5	+3	+1	0	-1	-3	-5
5. It would be easy for me to become skilful at using these digital tools	+5	+3	+1	0	-1	-3	-5
6. I would find these digital tools easy to use	+5	+3	+1	0	-1	-3	-5

Would you like to comment further?

_____

8.2 Evaluation criteria used for research phase 2

Was it your first time using roadmapping?

Please, mark your answers below using the provided scores.

Part 1 – Roadmapping Game Please select the responses that best describe your experience with the roadmapping game	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The game instructions were clear to guide me through it	+3	+1	0	-1	-3
2. The game material was easy to use	+3	+1	0	-1	-3
3. The time provided was appropriate for achieving the goals	+3	+1	0	-1	-3
4. The game help me with learning the roadmapping approach	+3	+1	0	-1	-3
5. I would recommend the game for other people	+3	+1	0	-1	-3
Part 2 – Digitalisation of Roadmapping Please select the responses that best describe your experience using the digital tools in the roadmapping game	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1.I found easy to learn the digital tools provided	+3	+1	0	-1	-3
2.I was able to use the digital tools to do what I wanted	+3	+1	0	-1	-3
3.My interaction with the digital tools was straightforward	+3	+1	0	-1	-3
4.The digital tools were flexible to help me with my game tasks	+3	+1	0	-1	-3
5.I would prefer using digital rather than paper tools for roadmapping	+3	+1	0	-1	-3

Please, comment further regarding why you would or not prefer using digital tools for roadmapping.

Would you have suggestions to refine the following applications of the roadmapping game?

Please, add any other comments concerning your experience today.

The digitalisation of roadmapping workshops

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