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Improving innovation implementation capabilities through implementation science and takt production principles in the infrastructure sector

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Abstract

Purpose – The infrastructure sector has long suffered from challenges in bringing innovations into practice. This study aims to investigate how adapting implementation science and takt production principles could improve the innovation implementation capabilities of organizations in the sector.

Design/methodology/approach – This research belongs to the field of innovation implementation. A design science research (DSR) approach is adapted for constructing, testing, validating and refining a novel model integrating implementation science and takt production. Within DSR, the theory-based initial model was introduced in a sector-wide workshop and tested, validated and refined through a case study in four Finnish public sector infrastructure organizations.

Findings – The results indicate that the innovation implementation capabilities of the infrastructure sector organizations have room for improvement and would indeed benefit from the adoption of implementation science and takt production principles. The participants felt that utilizing the constructed model (the TAIMI model) was both beneficial and challenging. Consequently, successful innovation implementation appears to be significantly dependent on organizational and implementation project-specific implementation capabilities. In addition to the implementation model, adapting these new approaches requires improving organizational capabilities and organized coaching.

Originality/value – Previous research focuses largely on theoretical or instructive settings, whereas this study adds to the understanding of how genuine and effective progress and improved implementation

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capabilities can be achieved. Together with a conceptual TAIMI model, the gained insights guide on how the tested principles can be utilized in improving infrastructure sector's productivity.

Keywords Knowledge management, Innovation, Process, Infrastructure, Productivity, Construction engineering management, Digitalisation

Paper type Research paper

Introduction

Previous research suggests that in general up to nine out of ten organizational innovation implementation efforts fail to achieve their goals in complex industries (Bauer and Kirchner, 2020; Fixsen *et al.*, 2009; McLean and Jiju, 2014). Since the infrastructure sector is complex, scattered, and in a constant flux of changes (Laitinen *et al.*, 2024; Tzortzopoulos *et al.*, 2005; Liljeroos-Cork and Laitinen, 2024), innovation implementation often experiences even greater challenges (Errida and Lotfi, 2021). Beneficial solutions and tools have been developed to resolve the needs and problems of the sector (e.g. Ofori *et al.*, 2021; Ikudayisi *et al.*, 2023; Adafin *et al.*, 2022), but adoption is proceeding insufficiently (e.g. Abbasnejad *et al.*, 2020; Olugboyega, 2024; Vidalakis *et al.*, 2019). This raises significant interest in how the innovation implementation capabilities of the complex infrastructure sector could be improved to enable the more effective adaptation of tools and methods that enhance productivity and workflows.

Implementation science aims at the effective adoption of innovations and focuses on uptake strategies, methods and processes (Bauer and Kirchner, 2020), but also recognizes the importance of fitting the arrangements to the context (Desjardins *et al.*, 2023). Innovation implementation outcome, efficiency and speed highlight the evolution of the culture, habits and practices of the community (McLean and Jiju, 2014; Abbasnejad *et al.*, 2020). Managing changes successfully in the complex infrastructure sector requires interactive linkages between administrative and operational activities (Liljeroos-Cork and Laitinen, 2024). Unlike the implementation sciences' assumption of a stable organization structure (Bertram *et al.*, 2015), the infrastructure sector's activities are commonly executed through project organizations that are typically temporary and project-specific (Lines *et al.*, 2015; Liljeroos-Cork and Laitinen, 2024). Thus, while containing many intriguing solutions, implementation science alone does not resolve the innovation implementation capability challenges of the complex and dynamic infrastructure sector. Therefore, this study seeks solutions from successful project executions of construction projects.

Interestingly, improved process flow, task-oriented scheduling, active process control and participatory planning are included as key elements in takt production – a concept originating from operations management research and further developed for improving construction project execution (e.g. Dlouhy *et al.*, 2016; Frandson *et al.*, 2013). In addition, takt production has been identified as a catalyst for pursuing systemic change in construction settings (Peltokorpi *et al.*, 2021). Takt production principles provide intriguing opportunities for supplementing implementation science with practical means that fit the infrastructure sector context. While there have been many efforts to solve infrastructure sector's challenges and improve implementation capabilities, to the best of our knowledge, there has been no comprehensive research or applications combining implementation science and takt production principles.

Thus, an interesting avenue for research arises in the form of our research question:

RQ1. How could combining implementation science with takt production principles improve the innovation implementation capabilities of infrastructure sector's organizations?

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Consequently, this work aims to examine how advantaging implementation and takt production principles could help in innovation implementation challenges. This paper introduces a novel implementation model for the pursuit of more effective implementation practices by adapting the principles of implementation science and takt production. Besides providing a tool for the more efficient deployment of unique targets, utilizing the model could presumably also lead to enhanced innovation implementation and processual capabilities that create the basis for improved future operations.

The research employs a design science research (DSR) strategy that consists of constructing, testing, validating and refining an implementation model that provides a structure for answering the research question identified in the diagnosis phase. The constructed implementation model is tested and validated through a case study in four Finnish infrastructure sector organizations: the testing embodies familiarizing the model to the case representatives and collecting feedback in workshops, and the case participants test the model independently to solve a practical organizational implementation project. Based on the results, the most interesting output of the research will be an insight into what kind of implementation capability impacts can be found by adapting implementation science and takt production principles. In addition, the study will produce a refined implementation model and an insight into the current capabilities and prerequisites of effective implementation in infrastructure organizations.

This paper is structured as follows. First, the problem is defined in this introduction, followed by presenting the relevant research background on implementation science and takt production in the theoretical background section. After that, the materials and methods of the study are introduced including the formulation of the initial model derived from the literature. The findings of the study are presented in the results section and discussed through the research question in the discussion section. Finally, the conclusions are presented based on the research findings and discussion.

Theoretical background

Innovation and innovation implementation capability

Innovations are necessary to drive the sustainability transition, improve resource efficiency and overcome challenges with productivity and performance in the construction and infrastructure sector (Adafin *et al.*, 2022; Akunyumu *et al.*, 2021; Granheimer *et al.*, 2025; *Rose et al.*, 2019). Examples of innovations in the infrastructure sector include circular material solutions, construction robotics and drones (Granheimer *et al.*, 2025), and Building Information Modelling (BIM) (Abbasnejad *et al.*, 2020). Innovations are commonly described as new, improving and nontrivial solutions that bring value to the organization (Akunyumu *et al.*, 2021; Sergeeva and Duryan, 2021; Adafin *et al.*, 2022). Innovations vary from technology and products to practices, processes, business models and services (Sergeeva and Duryan, 2021; Akunyumu *et al.*, 2021; Adafin *et al.*, 2022; Granheimer *et al.*, 2025). The pursued value of an innovation can only be achieved when the innovation has been successfully put into practice (Yusof *et al.*, 2022), which has traditionally been challenging in the infrastructure sector (Akunyumu *et al.*, 2021; Vidalakis *et al.*, 2019).

In scientific literature, innovation implementation capability is referred to, for instance, as the innovation diffusion process (Rose *et al.*, 2019), innovation readiness (Akunyumu *et al.*, 2021) and innovation adoption (Van Oorschot *et al.*, 2020). In addition to being an object to be implemented, an innovation can be comprehended as an outcome of ideation actions or a process of innovating (Granheimer *et al.*, 2025). In this paper, all these innovation approaches are taken into consideration, but the main focus is on the question of how to implement a defined innovation into practice.

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The infrastructure sector has long suffered from challenges in bringing innovations into practice. While innovations are at the core of improving operations and productivity (Adafin *et al.*, 2022; Granheimer *et al.*, 2025), innovation activities might end up being counter-productive when implementation fails (Vidalakis *et al.*, 2019). There are multiple challenges to sustainable and scalable innovation implementation in the infrastructure sector due to the sector's complexity and fragmented nature (Laitinen *et al.*, 2024; Tzortzopoulos *et al.*, 2005; Liljeroos-Cork and Laitinen, 2024), and the existence of unique projects with varying project-specific project organizations (Lines *et al.*, 2015; Rose *et al.*, 2019). Due to these challenges combined with deficient and heterogenous implementation capabilities (Chen *et al.*, 2025; Aldhi *et al.*, 2026; Yusuf *et al.*, 2022) innovation implementation is claimed to be insufficient (e.g. Abbasnejad *et al.*, 2020; Olugboyega, 2024; Vidalakis *et al.*, 2019; Yusuf *et al.*, 2022).

Furthermore, public or owner organizations have been considered central to implementing innovations in the sector through their projects, networks and operations outcomes (Rose *et al.*, 2019; Lines *et al.*, 2015; Aldhi *et al.*, 2026). Public organizations' capabilities that endorse successful innovation implementation include organizational resilience and enterprise architecture governance, the ability to arrange and govern successful and realizable projects, collaboration and stakeholder management, knowledge sharing routines and technologies, and transformational capabilities such as training, coordination and the integration of outputs into operations (Aldossari *et al.*, 2021; Chen *et al.*, 2025; Aldhi *et al.*, 2026; Yusuf *et al.*, 2022). Even though innovation capabilities in the infrastructure sector have been explored, there is little documented empirical research on validating the practical deployment methods of organizational implementation capability improvement (Lines *et al.*, 2015; Aldossari *et al.*, 2021).

Implementation science

Implementation science focuses on how and why practitioners adopt new practices (Fixsen *et al.*, 2009; Horner *et al.*, 2019), and it is seen to have its foundations in the 1970s medical research (Bauer and Kirchner, 2020) or else in the 1980s (Fixsen *et al.*, 2009). The inspiration emerged from the challenge of the non-adoption of evidence-based clinical innovations (Bauer and Kirchner, 2020; Fixsen *et al.*, 2009). The fundamentals, barriers, drivers, processes and concepts are increasingly studied, tested and refined (e.g. Desjardins *et al.*, 2023; Nilsen, 2015). Implementation science emphasizes the importance of actively engaging with and intervening in the context into which the innovation is introduced (Bauer and Kirchner, 2020; Bertram *et al.*, 2015). The main idea is to move from a passive "let it happen" and "help it happen" ideologies to active "make it happen" methods (Fixsen *et al.*, 2009). Thus, implementation science utilizes other sciences like the social sciences, economics and system sciences (Bauer and Kirchner, 2020; Nilsen, 2015). Previous studies note that education, feedback, audit and monitoring operations only result in the adoption of the innovation among a maximum of 5% of the target group (Bauer and Kirchner, 2020; Fixsen *et al.*, 2009). Implementation science suggests that the lag between evidence and widespread usage can be overcome by managing contextual factors rather than counting on effectiveness (Bauer and Kirchner, 2020). Overall, implementation science aims at finding effective strategies for moving innovations into daily performance and turning them into routine practices, hence genuinely and efficiently achieving the intended benefits (Bauer and Kirchner, 2020; Fixsen *et al.*, 2009; Nilsen, 2015).

Implementation science commonly builds on the core implementation components or implementation drivers, which are the key factors for outlining the basis for accomplishing successful implementation (Fixsen *et al.*, 2009; Nilsen, 2015). This study deploys the core implementation components introduced by Fixsen *et al.* (2009): staff selection, preservice and in-service training, ongoing coaching and consultation, staff evaluation, decision support

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data systems, facilitative administrative support and systems interventions. Bertram *et al.* (2015) categorize the components into three classes: competency, leadership and organization drivers. Indeed, each component or class should be carefully planned and organized with respect to the target and subject at hand. The core implementation components are integrated and compensatory by nature, which means that they can support, affect and cover for each other (Bertram *et al.*, 2015). The integrative and compensatory nature of the components brings flexibility and efficiency, but it also creates complexity and challenges in optimizing the adjustments (Fixsen *et al.*, 2009).

An implementation process can be divided into stages (Nilsen, 2015; Fixsen *et al.*, 2009), and this study adapts the refined implementation stages of exploration, installation, initial implementation and full implementation (Bertram *et al.*, 2015). The stages interact with each other and should be approached as a flexible and recursive process, where significant changes in personnel, funding or other factors might result in the need to readdress and reorganize the earlier stages (Bertram *et al.*, 2015; Horner *et al.*, 2019). Especially the first implementation stages aim at perceiving contextual barriers and facilitators, which requires bringing the context and focus from controlled research and development conditions to the conditions where the end-users of the intervention actually work (Bauer and Kirchner, 2020; Horner *et al.*, 2019). Horner *et al.* (2019) supplement this thinking by proposing the concept of resource leveraging. The essential idea is to exploit local demonstrations as the initial development and effect observation context, which offers an easy way of investing and initializing the implementation and gaining experience for refining the practices before the scaling-up phase and justification for the larger implementation investment (Horner *et al.*, 2019). To sum up, effective implementation engages end-users as early as possible in the process stages.

Takt production

Organizing targets and subjects through collaborative and participatory planning is at the center of takt production, and this turns our attention to examining takt production principles in the context of implementation practices. Takt production has seen a growing interest among construction operations management practitioners and researchers in recent years (Lehtovaara *et al.*, 2022). It originates from operations management research and focuses especially on the rhythm and manageability of activities to continuously produce valuable results and determinedly create conditions for subsequent activities (Hopp and Spearman, 2011; Lehtovaara *et al.*, 2021).

Takt production aims at dividing the project into a manageable and thus smaller batch size (Alhava *et al.*, 2019; Binninger *et al.*, 2018). The takt plan supports identifying and minimizing non-value-adding activities and allows a critical approach to time and inventory buffers (Lehtovaara *et al.*, 2022). Suitably small batch sizes bring the practical means to limiting the amount of work in progress (Linnik *et al.*, 2013) which enables and supports the implementation science principle of making the desired change effectively happen (Horner *et al.*, 2019). Another essential principle is pull production (just in time) (Lehtovaara *et al.*, 2022), which restrains starting new things before there is sufficient readiness to execute them effectively. The takt plan is based on identifying and dividing the project scope into logical entities (takt areas), arranging tasks into similar batches of activities (takt wagons), and arranging these batches into identical takt trains that each logical entity will face in turn (Binninger *et al.*, 2017). Identifying similar entities (standardization) supports reducing variability, which enhances the productivity of the work (Hopp and Spearman, 2011). As a result, the rhythmic takt plan fosters the improvement of project performance (e.g. Dlouhy *et al.*, 2016; Frandson *et al.*, 2013).

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Takt production identifies three levels of management: the strategic level is called high-level takt planning; the tactical level is called detailed takt planning; and the operational level is called takt control (Lehtovaara *et al.*, 2022). These management levels promote and enable improving, valuing and controlling the process flow (Lehtovaara *et al.*, 2022), a radical take-up of defects (Frandson *et al.*, 2013), and holistic performance with a discourse of balance between resource and process efficiency (Linnik *et al.*, 2013). Active control and participatory planning create channels for feedback and ideation and thus create a considerable condition for continuous improvement (e.g. Frandson *et al.*, 2013; Tommelein, 2017) that further feeds the preconditions for greater success.

Previous studies have demonstrated the focal potential benefits of takt production, such as reduced project duration and costs, better quality and outcomes, increased controllability and workload manageability, and improved communication, collaboration and problem-solving (Binninger *et al.*, 2018; Lehtovaara, 2023; Frandson and Tommelein, 2014). In addition, the approach seems to have a broad potential for various types of projects and operation improvements on different scales (e.g. Lehtovaara *et al.*, 2020b; Peltokorpi *et al.*, 2021).

Moreover, with such effects, takt production as a lean design management concept could be suitable for achieving high performance in expert work (e.g. Uusitalo *et al.*, 2019) besides the original use case of site activities. This encourages further experimentation with takt principles in other contexts such as for implementation purposes here. From these premises, takt production principles provide very interesting opportunities and transferability to implementation processes, yielding potential support for improving innovation implementation capabilities.

Materials and methods

Research strategy

DSR was used as a research strategy to effectively gain an understanding of the potential advantages of the adaptation of implementation science and takt production principles into infrastructure sector's implementation effectiveness. DSR is considered a suitable research strategy for this study as it provides a structured approach for systematically constructing, testing, validating and refining a practical implementation model that integrates implementation science with takt production principles; DSR allows us to address a real-world problem in close collaboration with practitioners, while similarly advancing the theoretical understanding of the phenomena (Holmström *et al.*, 2009). DSR supports research in the study's context, in which both the experimental settings and solutions are complex, and refinement must be iterated during and through testing (Kuechler and Vaishnavi, 2008). Moreover, implementation science and takt production principles both place practical and real-life work conditions at the center of effective transformation and steering activities. Caldera *et al.* (2019) suggest that implementation effectiveness should be perceived through real-life settings to observe the operability of the implementation process.

The study consists of four phases (guided by a DSR structure, e.g. Kuechler and Vaishnavi, 2008):

(1) diagnosis and definition of the problem;

(2) construction of the solution (the implementation model);

(3) testing, validating and refining the solution; and

(4) discussion of the findings and drawing conclusions.

The research flow is presented in Figure 1 and further elaborated below.

The diagnosis and construction of the model consist of looking for ways to employ both implementation science principles and takt production principles for organizational

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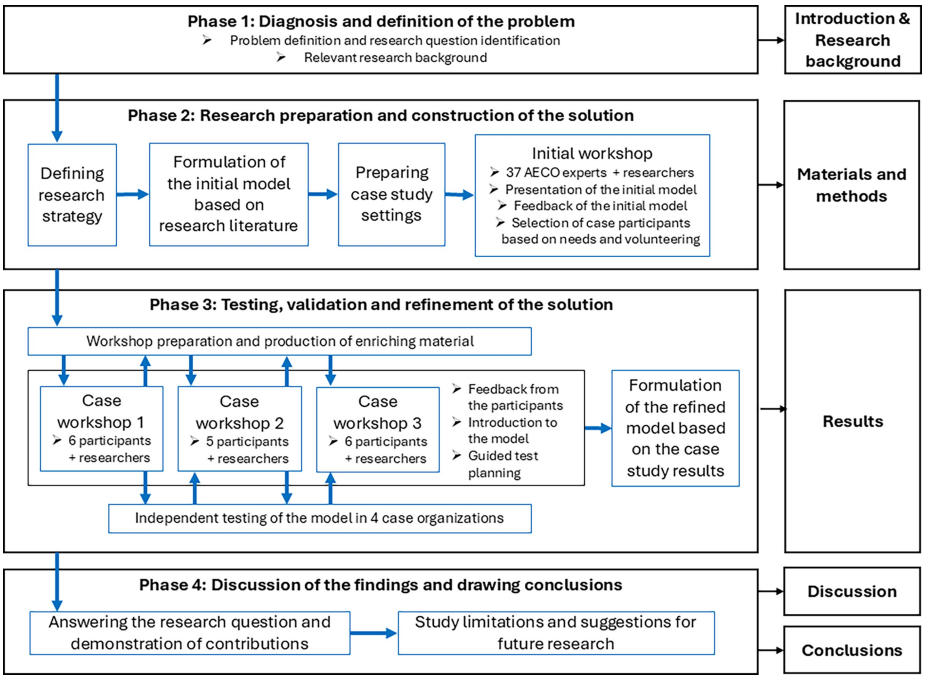


Figure 1. Research flow

improvement processes that can be demonstrated in practice and thus might support improving the implementation capabilities. Testing and validation of the solution is executed by testing the model in concrete implementation use cases, in which researchers act as facilitators. Therefore, within the DSR strategy, a case study was selected as the primary research method. A case study approach was adopted to conduct the testing and validation phase of the research, because it provides the opportunity to seek an understanding of the research topic in a real-life context (Saunders *et al.*, 2016). Refinement of the solution was executed firstly during the case study based on the participants' needs by primarily bringing in more details needed to proceed with the testing. Secondly, a more comprehensive refinement was carried out after the testing period based on the observations and feedback from the case workshops and by reflecting them in terms of the initial workshop outcomes. The research process was completed by discussing the main findings and demonstrating the study contributions and finally drawing conclusions based on them.

Formulation of the initial model

The initial model was formulated by bringing implementation elements into the conceptual takt production plan and using both implementation science and takt production principles to construct the contents. The implementation elements bring in the phases and key factors of an effective implementation process, which crystallize the prerequisites and methods for achieving the desired goals. The takt plan again provides a framework for the identification and formation of target groups at a conceptual level. Moreover, takt production principles foster the perception of the necessary levels of strategic, tactical and operational management

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in an implementation project enabling active control and effective execution to promote fluent performance. Together, these characteristics create a versatile and multilevel model for organization-wide implementation.

Combining implementation science and takt production principles create a largely compatible entity. In the initial model, the takt production logical entities are the different target groups of the implementation project, for example parts of an organization or specific processes. Implementation phases position themselves into takt wagons and thus form the implementation chain as a takt train. Following the takt plan framework, the takt trains are utilized at the operational level (takt planning), which covers the implementation target groups, and the tactical level (takt control), which is organized to steer the implementation project. At the operational level, there is an individual implementation chain for each target group, whereas at the tactical level, the chain expresses the progress of the whole implementation project. Finally, strategic management (high-level takt planning) responds to organizational management, where target group work management is organized and led, and high-level decisions are made. In the initial model these levels of management and actions of implementation are called the organizational level (level 1), implementation project (level 2), and implementation chains in target groups (level 3).

Interaction between implementation phases on levels 2 and 3 plays a crucial role. The interaction is intended to be arranged by a development group that is responsible for the implementation project. This group should act as implementation support for the target groups and arrange the planning, execution and communication of the implementation. The interaction carried out by the development group provides a direct channel for feedback from the target groups providing the refinement of the solution (implementation object), the implementation methods and organization of roles and responsibilities. According to the takt plan concept, the target group-specific implementation chains are arranged sequentially and overlap so that the amount of ongoing implementation activities is limited and enables strong support for each target group. The model allows for different kinds of setups with implementation crews as long as the parallel target group actions meet the amount of available implementation resources. Central to finding effective implementation support activities is building a strong understanding of the competencies and capabilities of the target groups, organizational management, and development group (Bertram *et al.*, 2015; Errida and Lotfi, 2021). Accordingly, the interaction between different levels establishes a basis for exploring, preparing and monitoring the development and launching improvement efforts of these innovation implementation capabilities.

Implementation capabilities are approached in this paper as a set of factors that enable achieving the adoption of innovation in a certain target group. In this paper, target groups are logical groups of practitioners or end-users whose behavior is expected to change as a result of the innovation implementation efforts (Bauer and Kirchner, 2020; Fixsen *et al.*, 2009). Furthermore, adoption turns the focus from developing a solution in controlled experimental circumstances to the ability to achieve eligible impacts through changing the practitioners' routines in their natural work environment (Bauer and Kirchner, 2020). Laitinen *et al.* (2024) suggest that in the infrastructure sector implementation capabilities include:

- vision;
- skills and abilities;
- collaboration;
- processes and incentives;
- technology;
- resources; and
- an action plan.

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Analyzing the implementation capabilities in the exploration phase is expected to support identifying how mature the capabilities are, and which capabilities require more attention to reach the topical goals (Laitinen *et al.*, 2024).

Data collection and data analysis

Initial workshop (phase 2). An initial literature-based model for combining implementation science and takt production principles was introduced at an initial workshop for 37 Finnish infrastructure sector experts to gain the practitioners' feedback on the initial model and to recruit participants for testing the model. The participants represented maintenance services, design and engineering companies, constructors, municipalities, governmental agencies, consultation and developer companies, digital/ICT services, and survey and asset management service providers covering director, worker and developer positions. Small groups served as the main working form and the workshop produced plenty of comments, questions, ideas and feedback on the initial model. The data consisted of small group documentation and research group notes from both small group discussions and discussions with the whole group. The data were collected and categorized to be utilized together with the case study data according to the coding framework presented in Figure 2. All small groups identified several use cases for the introduced implementation model. Based on the workshop feedback the initial model was verified to be attractive and opportune for testing and was named **TA**kt and **I**mplementation **M**odel for **I**nnovations (TAIMI).

Case study process (phase 3). The case study was carried out in 4 Finnish public sector infrastructure organizations. Each organization appointed 1–2 participants to the case study and selected a relevant implementation object to target their efforts to test the new model. The main focus of the case study was on TAIMI model level 3 (operational implementation with target groups), but feedback and observations were collected also regarding levels 1 (organizational steering) and 2 (implementation project). The implementation objects were targeted to ongoing change projects and all of them related to infrastructure maintenance. One of them focused on the definition/design phase of a maintenance work monitoring software and the others focused on the adoption/utilization phase of deploying new operational models including a rearrangement of winter maintenance works, adoption of new vocabularies (and arranging organization's operations accordingly) and adoption of a new information management system in maintenance operations. All case organizations were Finnish national and municipal infrastructure owner organizations and large by Finnish standards. To assess the generalizability of the case study the findings were compared and reflected against the initial workshop data and previous literature.

The case study was advised by researchers in three workshops in 2024 and implementation actions were performed independently by the participants. Each workshop introduced one or two steps of the implementation chain as a continuum, leading to a planned takt time of 7 weeks which was set in collaboration with the case participants. Capacity buffers were utilized as the primary buffers to allow flexibility in relation to the dynamic nature of their work, supported by secondary time buffers where deemed necessary. Each workshop's attention was also adjusted to serve the actual advancement of the cases. During the case study, the research group also produced additional and more detailed instructions based on the case participants' needs. The developed innovation implementation model was also assessed in the workshops and refined after the workshop series based on the participants' views and case experiences.

The case data were collected primarily in the workshops, each of which lasted four hours. The data consisted of observation notes systematically collected during the workshops. Additional data also included independent pre and middle tasks between the workshops, and

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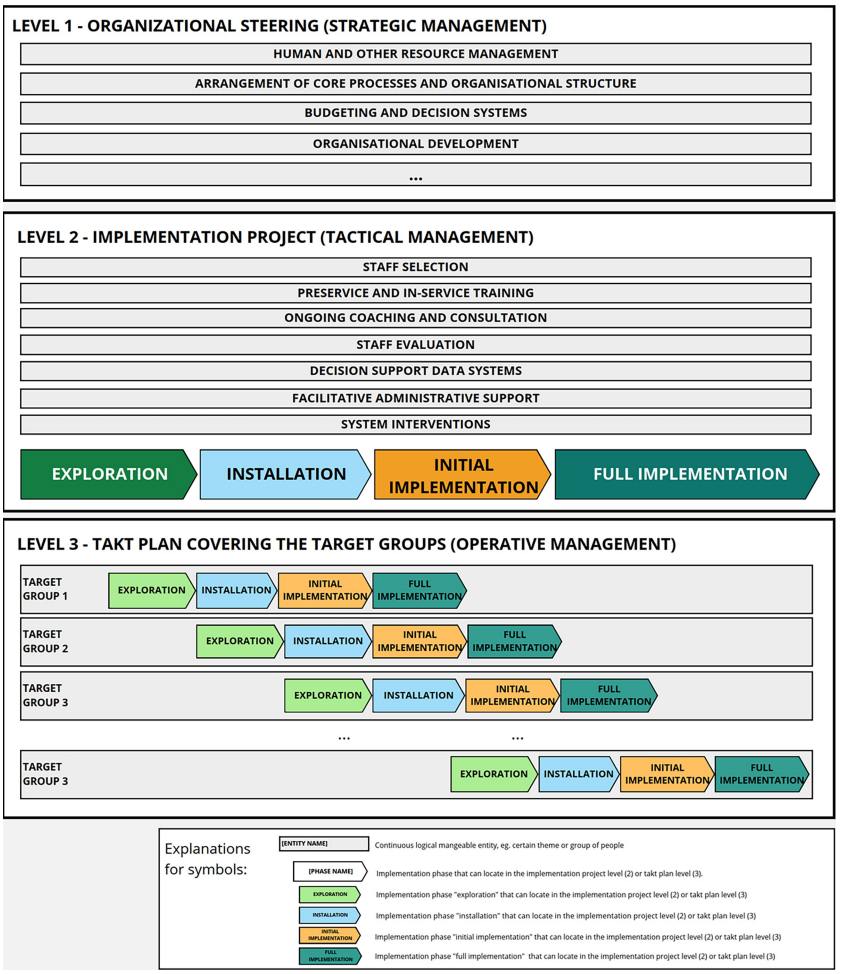


Figure 2. The initial model

draft versions of the implementation plans that were collected after each workshop. The data consisted of the experiences and ideas of utilizing the model and feedback regarding participation in the research. The data were independently documented by the researchers and compiled and validated together in research group meetings after each workshop. In addition, the results of the previous workshop were briefly reviewed with the case participants at the beginning of the next workshop. After the case workshops, the data analysis was carried out by first coding the compiled qualitative data into categories, then analyzing the data in each category, and lastly analyzing the whole results while reflecting onto the research question.

The coding framework of the qualitative data analysis is presented in Figure 3. The observation categories served as a framework for collecting notions from the initial and case workshops, and for identifying the key issues related to innovation implementation

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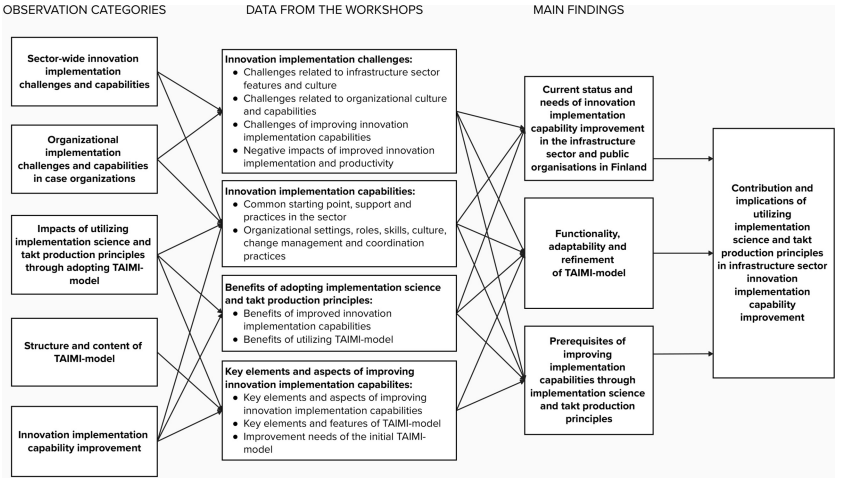


Figure 3. The coding framework

capability improvement. The main findings were produced by qualitatively analyzing the data and identifying the occurring and most significant aspects that support answering the research question.

Results

The results indicate that implementation and takt production principles possess the expected potential, but implementing new approaches requires support. The study aimed to gain insights into how advantaging implementation and takt production principles could help in innovation implementation challenges. The overall results from the initial workshop and the case studies are compiled in Table 1.

Innovation implementation capability improvement in the infrastructure sector and public organizations

The study revealed several challenges related to infrastructure innovation implementation. As shown in Table 1, the challenges stemmed from the features of the sector, but they were also the result of delayed and faint implementation efforts, and insufficient implementation capabilities. The case study indicated that the current organizational culture and operations in the case organizations are lacking coordination for change. In addition, practices for systematic and active steering, following and effective execution of the implementation projects appeared insufficient. This outcome is in line with the sector representatives' considerations in the initial workshop, that infrastructure sector innovation implementation initiatives are usually not organized properly and efficiently, which easily leads to the failure of the implementation. Overall, these results indicate that achieving the productivity impacts of innovations is hindered by their insufficient implementation.

The case study and the initial workshop revealed that innovation implementation capabilities and the selection of effective methods in use require much improvement. The case participants started and aimed at advancing the appointed innovation object implementation in their organizations, but they ended up arranging the level 1 and 2 elements in TAIMI-model instead of proceeding straight to level 3 execution. Although the

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Table 1. Key issues identified in the initial and case workshops

Theme	Innovation implementation capabilities and environment in the infrastructure sector and public organizations in Finland	Functionality, adaptability and refinement needs of TAIMI model	Prerequisites of improving implementation capabilities through implementation science and takt production principles
Innovation implementation challenges	Challenges related to infrastructure sector features and culture: • Vague and fragmented environment for implementation • Penalties emphasized, positive inducements underutilized • Active and competent individuals act as motors for change • Unclear or missing rights of (product/application) usage	Challenges related to organizational culture and capabilities: • Scarce resources for implementation (personel, time, money, technologies etc.) • Practical work processes are usually not documented Challenges related to organizational culture and capabilities: • Fragmented operations management and change management	Negative impacts of improved innovation implementation and productivity: • Decrease of available work due to more efficient processes (impacts to workforce and service producers) might cause resistance Challenges related to organizational culture and capabilities: • Fear for new things and change resistance are common • Reaching and engaging relevant participants Challenges of improving innovation implementation capabilities: • Lack of skills and common practices • Lack of available practical examples

(*continued*)

Table 1. Continued

Theme	Innovation implementation capabilities and environment in the infrastructure sector and public organizations in Finland	Functionality, adaptability and refinement needs of TAIMI model	Prerequisites of improving implementation capabilities through implementation science and takt production principles
			• Requirement of extensive knowledge in applying new principles
Innovation implementation capabilities	Common starting point, support and practices in the sector: • Typically poorly organized implementation • Innovation adoption leans typically on voluntariness instead of systematic implementation • Implementation seen as a separate phase after solution publication Organizational settings, roles, skills, culture, change management and coordination practices: • Insufficient commitment and vision for systematic and strategic implementation • Intra- and inter-organizational implementation efforts tend to fail	Organizational settings, roles, skills, culture, change management and coordination practices: • Systematic steering and follow-up of the implementation widely missing • Goals and activities normally well established, but execution and follow-up is missing • Implementation terminology is unfamiliar	Common starting point, support and practices in the sector: • Common implementation methods and practices are lacking Organizational settings, roles, skills, culture, change management and coordination practices: • Low maturity in the culture of continuous improvement • Implementation is sensitive to disturbances due to resource shortage and changes • Strength and enabler: motivation and sense of meaningfulness • Lack of sufficient participatory activities in implementation

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Table 1. Continued

Theme	Innovation implementation capabilities and environment in the infrastructure sector and public organizations in Finland	Functionality, adaptability and refinement needs of TAIMI model	Prerequisites of improving implementation capabilities through implementation science and takt production principles
	• Insufficient and vague organizational change management and coordination		
Benefits of adopting implementation science and takt production principles	Benefits of improved innovation implementation capabilities: • Revealed implementation challenge root causes Benefits of utilizing TAIMI-model: • Improved communication • Tools for achieving a desired cultural change • Systematic advancing, effective and better targeted activities • Increasing target group commitment and tackling change resistance	Benefits of utilizing TAIMI-model: • Identifying and engaging relevant target groups • Perceiving of the practical work processes • Platform for effective tools and methods • Increased efficiency and benefits of piloting • Identifying effective implementation activities, improved sense of control • Structure for organization-wide scaling	Benefits of improved innovation implementation capabilities: • Information exchange and best practice benchmark • Dynamic and adjustable basic methods Benefits of utilizing TAIMI-model: • Clarifying goals and implementation objectives • Creating feasible action plan, faster overall progress
Key elements and aspects of improving innovation implementation capabilites		Key elements and features of TAIMI-model: • Implementation and change management skills ramp-up • Bottle necks, challenges and risks management • Maturity levels and variety of maturities	Key elements and aspects of improving innovation implementation capabilities: • Sufficient adoption support for new principles

(*continued*)

Table 1. Continued

Theme	Innovation implementation capabilities and environment in the infrastructure sector and public organizations in Finland	Functionality, adaptability and refinement needs of TAIMI model	Prerequisites of improving implementation capabilities through implementation science and takt production principles
		• Decision making and decision gates • Human-centricity, motivation building and resistance mitigation • Roles and responsibilities, steering/ implementation group • Interaction channels, multi-channel communication • Improvement management, variety of means and methods • Quality of implementation results (appropriate adoption) • Description of practical work process (of target group) • Tools and methods selection for effective implementation	• Breaking down the deployment of new principles and methods • Start from level 2 exploration, adequate allocation for early phases • Practical examples

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participants did not achieve changes in the target groups' behaviors during the case study, they reported that the implementation projects had progressed considerably through identification and resolution of key organizational barriers. Before systematic implementation on the target-group level, it became necessary to establish the intervention settings, organize the overall implementation project, and clarify the implementation prerequisites, objectives and goals. Furthermore, proceeding along the planned schedule was challenging due to a lack of resources and personalization, the specification and change of the original implementation goals and actions during the study, and the organizations' significantly lower than expected readiness to execute the implementation. Instead of proceeding with target groups, the participants focused on and received support for structuring and arranging their implementation projects, identifying implementation bottlenecks in their organizations and, finding solutions for promoting their objectives. The results indicate that the capabilities regarding level 2 (implementation project settings) and level 1 (organizational arrangements) are currently rather low in maturity, which challenges the successful execution of the level 3 target group implementation chain. These results suggest that efforts should be put into improving organizational implementation capabilities, as they are currently widely deficient and have a significant effect on the implementation success.

The results further indicate that the innovation implementation success in organizations depends on certain individual people and their opportunities and abilities to focus on the implementation. In all organizations, innovation implementation was a very thinly occupied project that was placed in the hands of only one or two people. Furthermore, the implementation was typically only one minor task in their entire workload. In one organization, two innovations were joined in the first case workshop when the participants realized that making too many changes at the same time would only confuse the target group instead of putting their work in order. In another organization, the implementation object switched after one of the two participants left their job and the other one was left alone with too few resources to manage the original implementation object alone. In the third case a new employee was recruited during the study, where the object was originally the definition phase of a software development project. However, during the case study the aim of the development endeavor was clarified and led to the insight of the actual object perhaps being rather a renewal of the related operational model. The fourth case was organized with a service provider as an extra resource and implementation specialist because the implementation was only on the solitary case participants' shoulders and the case object covered the whole organization with significant effects on inter- and intraorganizational operations. This case proceeded quickly after a slow start. In all organizations a flood of continuous and unpredictable changes seems to challenge the practical work and the implementation of effective improvements. Overall, the results suggest that allocating and training human resources for implementation is one of the most notable hindrances/enablers for innovation implementation capability improvement.

Implementation science and takt production principles bring novel approaches to innovation implementation in the infrastructure sector. Potential benefits for the whole sector based on the initial workshop results include improved communication, implementation challenge root cause identification, and tools to achieve cultural change. Reported benefits from the case studies include an increase in target group commitment, improved tackling of change resistance and systematic advancement with effective and better targeted activities. Taken together, these results suggest that implementation science and takt production principles possess a potential to improve innovation implementation capabilities by

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identifying the critical capabilities to be enhanced and by offering tools and methods to improve these capabilities.

Functionality, adaptability and refinement of the TAIMI model

The results indicate that it is possible to construct an implementation model that integrates implementation science and takt production principles to be useful, practical and effective in organizational implementation needs. Implementation science and takt production have many similar principles. Limited batch size, participatory planning and the division of the execution into phases are among the most important principles. The takt production brings an operable framework to structure an implementation project where the most central elements of implementation and takt production can be easily arranged. Interestingly, implementation and takt production principles appear to fit well together and complement each other.

While acknowledging the potential benefits, the case participants noted that the TAIMI model should be further developed to be more easily comprehensible and adaptable. The participants' feedback indicated that the preliminary model as such might be simultaneously too simplistic and too complex. The case study participants expressed a need to complement and modify the model to support adoption, reflect more iterative characteristics, and guide a step-by-step progression. The case participants proposed ideas and the needs to developing the model, such as producing tools and materials to instruct the maturity assessment, structuring the target groups into sets of main target groups and sub-target groups, addressing the owner of the main target group as a member of the community of practice and arranging the recurrent elements of implementation into continuums crossing the implementation phases. The case workshop discussions also highlighted the need to add phases to the implementation chain for the clear preparation of the initial implementation, implementation responsibility reorganization between the initial and full implementation, and the ensuring of continuous improvement practices to create the basis for fluent updates along the proceedings of the implementation project. In summary, the results suggest that the principles of the model are impressive, but breaking down the adaptation and understanding the model's extensive content requires help.

Based on the case study findings, the TAIMI model was refined. First, new phases of "preparation," "launch preparation" and "ensuring implantation" were added to the implementation chain. The purpose of the "preparation" phase is to agree on the scope and execution of the initial implementation. The "launch preparation" phase was noted necessary for making a shift in the corresponding roles. The purpose of "ensuring implantation" is to secure that the implemented innovation transforms into a natural and continuously improved part of the practical work. Second, implementation components on levels 1 and 2 were restructured and enriched to ease the progress. For example, the implementation project level was enhanced by bringing in elements covering the capability assessment. Third, more emphasis was given to collaboration structures between the different levels. This was promoted, for instance, by bringing pilot target groups from level 3 to the exploration phase on level 2 and organizing the main target group owners to represent and link the community of practice. The researchers noticed that structuring the main and sub target groups was necessary to help to perceive and manage the complexity and relationships of steering the operations that exist in the public-sector infrastructure organizations. The refined TAIMI model is presented in Figure 4.

In addition to the enforced changes in the TAIMI model, several additional initiatives and possibilities remain to further develop the model. One of the most significant is a signal of the potential need for an additional portfolio management level between the organizational and implementation project levels. The participants wanted supporting tools and instructions.

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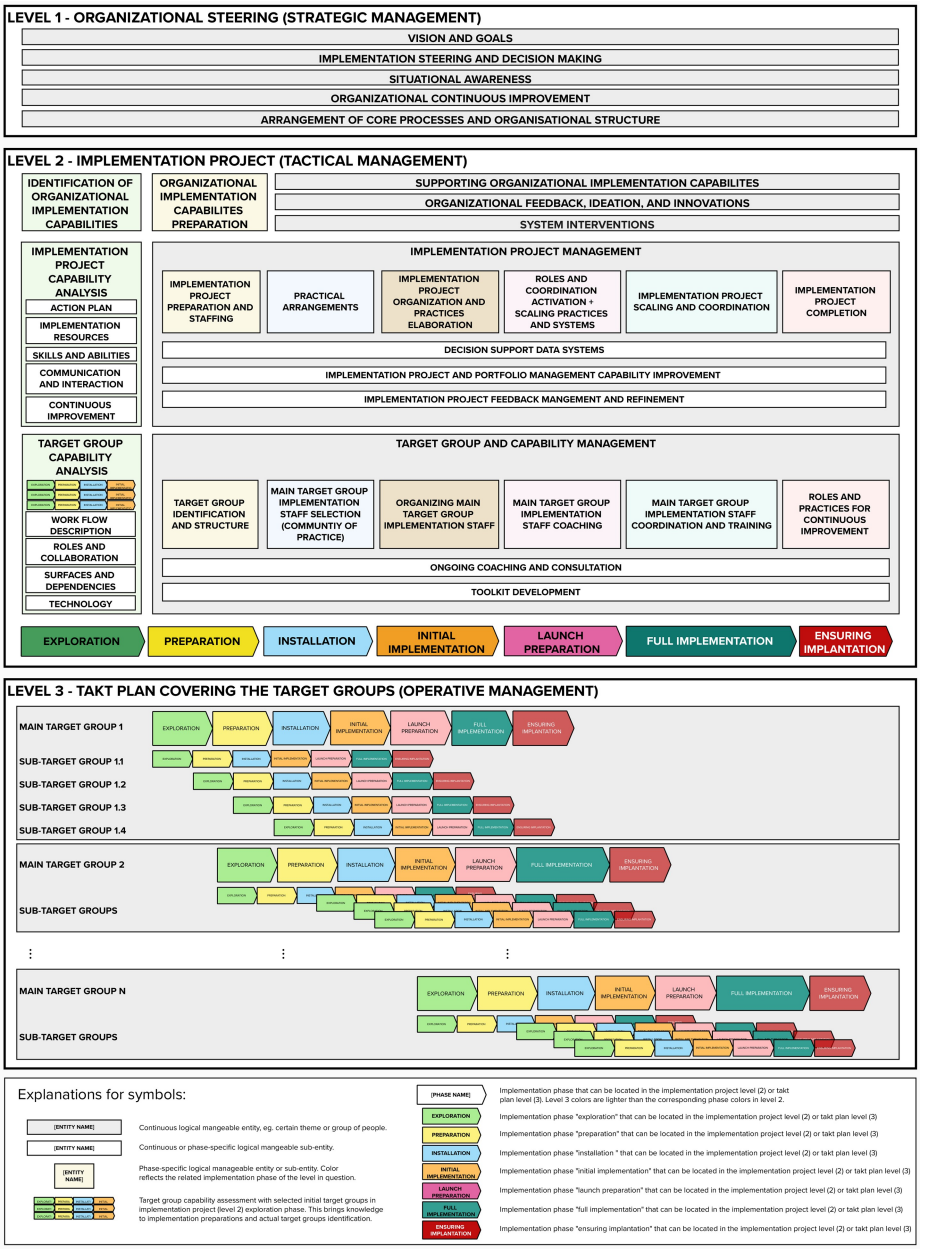


Figure 4. Refined TAIMI model

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To sum up, the feedback from the case study participants and results of the research encourage further study, testing and refinement of the model.

Prerequisites for improving implementation capabilities through implementation science and takt production principles

Overall, the participants reported that they were very satisfied with testing and utilizing the TAIMI model. The researchers noted that the participants were very active and capable of open-minded thinking, which enabled them to gain plenty of tools and benefits from taking part in the study. The participants were able to clarify the overall picture and define the path forward, including the necessary measures to solve the problems encountered during the implementation. They stated that dividing the innovation implementation project into phases and target groups improved the feeling of mastery in their efforts. Another advantage stated by the participants was that the identification of key stakeholders and hindrances enabled them to focus on the most relevant target groups and factors. They felt that listening to the target group and perceiving their premises advanced the identification of effective measures and aligned the aims of operative and strategic workers. In summary, the key benefits from the case study for the participants were clarifying the goals and solutions and identifying the bottle necks and target groups to define and execute effective activities. The participants reported that participating in the case study process was very beneficial and rewarding. The researchers noted that the participation and the principles gathered in the TAIMI model brought a quite novel and pivotal approach to implementation with an emphasis on user-centricity, diligent and systematic arrangements, and the importance of iterative and practice-targeted measures. These new aspects are gathered in Table 2, and they required familiarization and adoption with strong support and facilitation from the research group.

The participants considered that the case workshops provided an opportunity to stop in the middle of busy everyday life to examine, plan and promote their own implementation matters. In addition to the TAIMI model and guidance given by the researchers, the participants felt the facilitated small peer group was a very necessary method for advancing their implementation cases. This made it possible to bounce ideas around, give input to open one's own thinking, and create proper pressure to advance one's plan through mutually agreed dates. The participants expressed a desire for similar facilitated small group methods to occur more commonly in the infrastructure sector. The most convincing evidence of their satisfaction was that they asked for a continuation of the research so that they could continue the facilitated and peer-supported adaptation of the TAIMI model and innovation implementation methods.

The case study revealed that the TAIMI model contains many new approaches with respect to carrying out an implementation project. First, adapting the takt plan framework instead of one huge implementation group opens a view to different needs, target-group-specific solutions and the potential of learning from doing. Second, a fit for purpose instead of fit for all or fit for solution enables the tailoring of implementation actions and operations based on the maturity of the target group. This means that instead of executing a predefined set of implementation procedures there is a human-centric and practical work-based planning of implementation actions together with the target group members. Third, achieving iterations and agility instead of prefixed frames and solutions requires learning and an open mind for finding the central needs of the target groups as well as timely and active feedback. Taken together, these results suggest that achieving effective implementation capabilities through adopting the TAIMI model principles requires an effort to rebuild the mental models in infrastructure sector operations.

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Table 2. Traditional innovation implementation practices in the case organizations compared to practices based on the TAIMI model

Theme	Traditional practice in the case organizations	Practice based on implementation science and takt production principle
Implementations' role and timing	Implementation is planned after the solution has been developed	Implementation planning and preparation is a relevant part of developing the solution
Segmentation	Target audience approached as homogenous group and implementation launched as one entity	Audience is structured in target groups, in which implementation execution proceeds in waves
Implementation planning	Development group plans the implementation actions	Target groups are involved to plan and carry responsibilities of implementation actions planning and execution, development group coordinates
Implementation methods	Same implementation methods for the whole audience, implementation actions typically separated from daily work tasks (e.g. mass communication and training sessions)	Implementation actions are connected to existing points of the work process of the target group. Methods and support for each target group are arranged based on the capabilities and premises of the group
Follow-up, feedback, iterations	Implementation follow-up and feedback is on general level and development iterations are executed typically in large packages	Testing and refinements are made amongst practical work environment in initial implementation groups before scaling (follow-up and feedback collected from each target group)
Impacts and continuous improvement	Stabilizing of new practices and impacts of the implementation are left with little or no attention	Stabilizing of new practices is ensured and impacts are identified through capabilities maturity level assessment

The researchers observed that improving the innovation implementation capabilities through introducing new methods and principles requires "implementation of implementation methods." The current innovation implementation capability of the infrastructure sector is generally low based on the study results. Compared to this starting point, the number of new principles and methods gathered in the TAIMI model is vast. Thus, the case participants suggested that it would be beneficial to offer step-by-step guidance and practical examples to support adoption. In addition, the researchers noted that the adoption of TAIMI model and new principles requires sufficient support and facilitation. To summarize, based on the findings the most essential prerequisite for improving implementation capabilities appears to be regular facilitative support and coaching from experts with experience of utilizing implementation science and takt production principles.

Discussion

The main goal of this study was to gain an understanding of how implementation science and takt production approaches could help in solving innovation implementation challenges in infrastructure sector's organizations. The theoretical and practical contributions of the study are reviewed in this section. Together, these contributions broaden the knowledge of the challenges, benefits and prerequisites of implementation and takt production adoption.

First, the theoretical contributions broaden the empirical knowledge of the challenges, potential impacts and adoption prerequisites of utilizing implementation science and takt production principles in the infrastructure sector. Considering the implementation capability impacts discovered, the results are reflected against capability elements provided by Laitinen *et al.* (2024). During the case study, a significant improvement was achieved in vision and

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goal setting, skills and abilities, processes and incentives and action planning. These elements are in accordance with the exploration and installation stages of implementation (Bertram *et al.*, 2015) and largely included in the aims of high-level and detailed takt planning (Lehtovaara *et al.*, 2022). As a result, the results of this investigation show that implementation science and takt production principles provide a beneficial and novel approach to improving both organizational development processes and managing and identifying the status of innovation implementation capabilities.

Several implementation capability challenges were identified during the study. Implementation resources repeatedly appeared as a critical challenge, but the participants did not deliberately concentrate on resolving resource-associated issues during the study. The scarcity of implementation resources has been acknowledged and turned into a solution called resource leveraging in the previous implementation studies by Horner *et al.* (2019). Finally, collaboration and technology were handled as the content of implementation action planning, but they were not actually affected. Another finding is that most of the innovation implementation capability issues appeared at the organizational and implementation project level. This finding is consistent with the international implementation literature reviews of Abbasnejad *et al.* (2020) and El-Adaileh and Foster (2019), who propose that implementation difficulties and success relate heavily to organizational implementation capabilities. Rose *et al.* (2019) had similar findings regarding innovation implementation challenges in their study covering client, contractor, supplier and consultant organizations. Overall, the case study results indicate that implementation capability issues especially concern organizational change management and implementation project management.

Turning to the prerequisites of adopting the principles of the TAIMI model, the case participants felt that the new principles are beneficial but challenging to adopt independently. Thus, the role of both implementation and takt production in this paper is two-fold. On the one hand, they provide the means to improve innovation implementation capabilities, and on the other hand, they are also objects to be implemented. However, adapting and advancing a novel implementation model with transformative principles requires learning, coaching and training of these principles. These findings reflect those of Liljeroos-Cork and Laitinen (2024), who also found that in the infrastructure sector, artifacts such as tools and documents and processes are the emphasized methods, whereas human roles and discussion tend to possess an interesting and under-advantaged potential. Therefore, in addition to adapting the new principles, there should be a comprehensive focus on the methods to achieve transformation of adopting the new principles, mindsets and basic concepts.

Although this study focuses on the utilization of implementation science and takt production principles, the findings may well have a bearing for their body of research. The results may be of great interest to implementation scientists since they shed light on the methods and prerequisites for the implementation of implementation science concepts. In addition, the findings suggest that for the infrastructure sector, the implementation stages contain three supplementary phases: preparation, launch preparation and ensuring implantation. In terms of takt production research, an interesting viewpoint is the conception of takt time in implementation cases. Adopting a takt plan as a framework for an implementation plan at the conceptual level without considering the idea of a standardized takt time might lead to conflicts between operational implementation proceeding (takt control level) and implementation resources (takt planning level). Controlling the takt "beat" rests upon unified identifiable replicable elements with a defined takt time (e.g. Binninger *et al.*, 2017). Even though in theory the implementation phases could be packaged this way, the results of the study indicate that the occasion-specific needs might lead in practice to different durations of the same implementation phase in different target groups. Furthermore,

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it seems that different implementation phases might demand different takt times. Consequently, this might result in challenges regarding the manageability of the implementation project schedule and the coordination of different target groups and, thus, a fluctuation in the need for the required implementation resources/staff. Although uniform takt time (at least within a single phase) is a vital mechanism to ensure the adequacy of implementation resources and to adhere to takt production principles, following a uniform takt time was observed to be challenging in practice, potentially due to the participants having little prior experience working with takt production principles. Simultaneously, deliberate control scenarios (that would potentially be triggered by following various KPIs) were not adequately designed in the planning phase that further hampered the capability to follow set takt time when something unexpected happened. These notions correspond with findings from low maturity takt production cases in construction production (Lehtovaara *et al.*, 2020a) and highlight the need for a particular effort to improve maturity in future implementation cases. On the other hand, the case participants stated that the case workshops were an important impulse to advance and update their implementation plans. This indicates that regular status and planning sessions might be important means to ensuring and speeding up the execution lead-time. Thus, it seems that for implementation purposes, takt should also be utilized as a strategic and a tactical activity rhythm. Taken together, the selection of takt time, more deliberate selection of buffers, anticipating potential control scenarios (with adequate KPIs) and in overall aiming for higher takt maturity over time should be examined more in future implementation case investigations.

The study offers recommendations on how practitioners can improve their innovation implementation capabilities and activities. The study introduces a conceptual and novel TAIMI model for effective implementation. The case study findings support the assumption that the application of implementation science could benefit from the structures of takt production to facilitate the feasibility and project-approach of the implementation. The participants considered the case study successful and reported that they gained support in clarifying the bigger picture of their cases, proceeding with their efforts, recognizing effective actions, and identifying organizational challenges and improvement objects. One of the most interesting results was that the participants regarded early target group orientation as a new and strikingly important approach to innovation implementation. Importantly, involving target groups in the tactical and operational management of a project is one of the most central principles in both implementation theories and takt production (Horner *et al.*, 2019; Lehtovaara *et al.*, 2022). The finding of the demand for taking the different premises of different target groups into consideration is also supported by Vidalakis *et al.* (2019). Hence, the results provide evidence of the potential benefits of advancing implementation and takt principles in the form of the TAIMI model, but also revealed a demand for building capabilities for understanding, adapting and utilizing it.

The findings can support infrastructure sector organizations in enhancing the flow of work and hence support work well-being, improve resource efficiency through reducing waste, and enhance efforts to achieve objectives and impacts efficiently. The potential use cases of the constructed TAIMI model are numerous, such as implementing new tools and operational models, improving current procedures and processes, and enhancing implementation capabilities and the manageability of operations. In addition, the model supports improving processual maturity and actions evolving from reactivity to proactivity and innovation, which supports strengthening resilience and competitive advantages. As a result, this study contributes to the existing knowledge of development in the infrastructure sector by providing the means to move toward better capabilities in effective implementation.

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Conclusions

This study was designed to determine how combining implementation science with takt production principles could improve the innovation implementation capabilities of the infrastructure sector's organizations. The case study results imply positive effects for innovation implementation capabilities through constructing and testing the conceptual TAIMI model. Adapting the model supported clarifying the implementation vision and goals, enhancing skills and abilities, considering the processes and incentives of the target groups, and producing an operable action plan. Taken together, the results support the initiative of adopting implementation science and takt production principles in the form of the TAIMI model, but at the same time they underline the necessity of ensuring adequate coaching and organized arrangements.

While the case study is limited to four Finnish public infrastructure owner organizations, the overall data coverage is considerable, and the findings also reflect the previous general research results considering innovation implementation capability issues. Hence, the results might also be relevant to other actors and regions. Implementation efforts are easily directed to technological and processual aspirations, which underlines the importance and underutilized potential of focusing on human and organizational innovation implementation capabilities. Thus, this new understanding can be a starting point for improving the innovation implementation practices and capabilities of infrastructure sector organizations. Furthermore, this is an interesting and fruitful area for further research to explore organizational innovation implementation capability identification and enhancement in other countries and sectors. Continued efforts and longitudinal research are needed to refine and reveal the full potential of the TAIMI model. In addition to organizational development, the implementation and takt production principles show the potential for wider interorganizational development initiatives in the infrastructure sector.

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