Productivity development enablers in the infrastructure sector: capability maturity model integration approach

Kaisu Laitinen, Mika Luhtala and Maiju Örmä
Tampere University, Tampere, Finland, and
Kalle Vaismaa
Research Centre Terra, Tampere University, Tampere, Finland

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Abstract

Purpose – Insufficient productivity development in the global and Finnish infrastructure sectors indicates that there are challenges in genuinely achieving the goals of resource efficiency and digitalization. This study adapts the approach of capability maturity model integration (CMMI) for examining the capabilities for productivity development that reveal the enablers of improving productivity in the infrastructure sector.

Design/methodology/approach – Civil engineering in Finland was selected as the study area, and a qualitative research approach was adopted. A novel maturity model was constructed deductively through a three-step analytical process. Previous research literature was adapted to form a framework with maturity levels and key process areas (KPAs). KPA attributes and their maturity criteria were formed through a thematic analysis of interview data from 12 semi-structured group interviews. Finally, validation and refinement of the model were performed with an expert panel.

Findings – This paper provides a novel maturity model for examining and enhancing the infrastructure sector's maturity in productivity development. The model brings into discussion the current business logics, relevance of lifecycle-thinking, binding targets and outcomes of limited activities in the surrounding infrastructure system.

Originality/value – This paper provides a new approach for pursuing productivity development in the infrastructure sector by constructing a maturity model that adapts the concepts of CMMI and change management. The model and findings benefit all actors in the sector and provide an understanding of the required elements and means to achieve a more sustainable built environment and effective operations.

Keywords Productivity, CMMI, Continuous improvement, Change management, Capabilities, Maturity, Infrastructure system, Lifecycle

Paper type Research paper

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1. Introduction: from productivity concerns to productivity development

In past decades of the digital era, the productivity of construction industry has not improved in the same speed with other industries, which indicates difficulties in achieving resource efficient and digitalized built environment activities. In recent years, improving productivity has gained a lot of attention in the construction and infrastructure sector. Reports and programs (e.g. Barbosa *et al.*, 2017; Finnish Government, 2019) suggest that the productivity of the sector could be considerably improved, both globally and in Finland. This paper focuses on infrastructure sector as there are several significant reasons why productivity in the sector should be improved, including the financial pressure of decreasing maintenance costs and the increasing repair needs of aging infrastructure (Lee *et al.*, 2015; Aziz *et al.*, 2017; Munir *et al.*, 2020).

There are studies that aim to grasp and consider the productivity development of construction activities on industry level. Ofori *et al.* (2021) consider initiatives that enable contractors to improve construction productivity. Emphasizing the private sector's value creation logics, top motivations for contractors are based on profit maximization. However, most of the important productivity improvement strategies are not in the control of contractors but in the hands of government and design (Ofori *et al.*, 2021). Javed *et al.* (2018) provide a perspective on factors that drive or constrain construction productivity development based on the political, economic, social, technological, legal and environmental (PESTEL) analytical framework. They present five strategic aspects (policy formation; regulatory requirements; planning and design; project management and administration; site construction) that contain these factors, and they show the interconnectedness and messiness of the interrelationships of the factors. They suggest the formulation of holistic strategies for utilizing the drivers and for inhibiting the constraints systemically. While there is research interest in relevant change instruments, this paper argues for a need of a view that considers how to enable the doing of change.

This paper adopts the capability maturity model integration (CMMI) approach to construct a framework for identifying the enablers that improve the productivity development capabilities and hence, enable the productivity development of the infrastructure sector dynamically. Thus, CMMI framework provides a tool for perceiving an effective strategy for productivity development. Through the research question: "*What kind of a capability maturity model can help in identifying the enablers of productivity development in the infrastructure sector in Finland?*" a CMMI inspired model is constructed by forming a framework of key process areas (KPAs) and maturity levels through literature, indicator attributes and their maturity criteria through 12 group interviews (45 interviewees) and validation through a panel of five experts.

This paper is structured as follows. Section 2 presents the theoretical backgrounds for understanding the productivity of infrastructure sector and CMMI approach. Section 3 introduces the methods for constructing the model and processing the data. Section 4 presents the findings, the model and discusses the results. Section 5 draws conclusions.

2. Theoretical background

This section describes the key issues regarding productivity development in the infrastructure sector. To understand productivity development in the infrastructure sector, one first needs to recognize the nature of the sector and examine productivity from its perspective. After that, CMMI is presented as an approach to evaluating the maturities of the needed capabilities and thus identifying the productivity development enablers. CMMI can be considered as a segment of change management.

2.1 Infrastructure sector and productivity: a general perspective

The infrastructure sector is a complex system consisting of physical infrastructures and involved actors creating, managing and maintaining them. Physical infrastructure systems are, for example, transport networks and urban areas, water supply and sewage, energy and communication networks and environmental properties and resources (Lee *et al.*, 2015). Activities in different infrastructure lifecycle phases, such as construction, design and maintenance, are closely associated with each other, as well as other operations like permitting procedure and control of use (Padgett and Vishnu, 2020; Javed *et al.*, 2018). Additionally, infrastructure boundaries are somewhat indistinct because built environment elements and systems interact intensively with each other (Padgett and Vishnu, 2020). For example, the same energy network might serve and be a part of both a traffic light system and a building at its region of operation. At the same time, a part of a certain infrastructure system can involve several other systems. For example, a road section can involve different traffic user groups, a pavement, drainage, lighting, road markings and signs. Furthermore, an actor might own or operate several different systems and physical asset types. It is hard to define the infrastructure sector comprehensively. It can be understood as a constellation of functions that strive to provide a built environment and enable physical facilities for society, including the social organization of people in these functions.

Productivity as a concept is ambiguous, and it is applied in multiple meanings. Productivity is generally defined as the ratio between outputs and inputs. This paper approaches productivity as a rationality which aims to achieve optimal actions or results (cf. the concepts of "performance"; "effectiveness"; "efficiency"; cf. Lebas and Euske, 2007; cf. Forbes and Ahmed, 2011, 1 and 23). One might also consider the connection of "productivity" to the literature and concept of "public value" (Moore, 1995) in the context of the infrastructure sector when infrastructures are understood as societal services.

Productivity might differ for different parties in the same situation. Different actors have different perspectives of what the output should be. Furthermore, there are differences regarding the value creation logics of various sector actors: public organizations, as clients, seek value for money from a taxpayer perspective, while private actors seek profitability for shareholders. In addition, there are differences and conflicts among different private actors' productivity views when they collaborate in the same project. However, there are common value systems between these actors, such as "efficiency", i.e. using minimum means to achieve certain ends (van der Wal *et al.*, 2008; Johanson and Vakkuri, 2017). This idea is the focus and glue of this paper: enhancing productivity (cf. "efficiency"; cf. "performance") of any actor improves the potential productivity of the whole, but only when this partial optimization is consistent with serving the end users and customers of the infrastructure sector.

Productivity can be examined on multiple levels in infrastructure sector (cf. Ofori *et al.*, 2021; Rosen *et al.*, 2019; Munir *et al.*, 2020; Lee *et al.*, 2015; Javed *et al.*, 2018). System level productivity reflects the inputs and processes needed to ensure the operability of the targeted system, such as a traffic network, an energy system, or in more detailed scale road drainage (Rosen *et al.*, 2019). Furthermore, the system level should also consider the existence of sub-systems (Munir *et al.*, 2020). Many studies (see Ofori *et al.*, 2021) focus on construction productivity from the perspective of project or activity. On the other hand, sector level is traditionally seen as a stakeholder to developing construction productivity. In addition to construction, activities to maintain the desired service level of the infrastructure system are governance, information management, network planning, maintenance optimization, demand control and other (Javed *et al.*, 2018), i.e. elements of asset management. Construction is often considered to position on the project and organizational levels, whereas sector level productivity should take into consideration the value that the physical infrastructure and sector's operations bring to society as a whole (Lee *et al.*, 2015). In this paper, infrastructure sector productivity means the efforts to create and maintain the built environment for the needs of the end users.

2.2 CMMI as an approach to achieve productivity development

This paper approaches productivity development as a continuous endeavor for improvement, where capability building and maturity evaluation are seen as central concepts. Furthermore, the infrastructure sector productivity improvement requires holistic total optimization for infrastructure to serve its users appropriately. In other words, development processes should be examined as a systemic and multilayered entity that recognizes linkages between individuals, projects, organizations and infrastructure systems. In this vein, this paper seeks the maturity development needs for capabilities of implementing the productivity improvement measures that previous research like Ofori *et al.* (2021) or Munir *et al.* (2020) has identified.

Continuous improvement of productivity requires capability for development processes. Wendler (2012) describes capability as "*the power or ability in general . . . to fulfill specified tasks and goals*". Ariffin and Ahmad (2021) suggest that capability building is "*a process by either individuals or organizations to strengthen and maintain the ability to achieve organizational objectives over time*". In this study the examined organization is infrastructure sector, and the objective is to improve productivity development capabilities.

Key contributors for perceiving potential paths to improved capability for development processes are conceptualizing the maturity levels and identifying the current state and deficiencies (CMMI Product Team, 2010). Related to capabilities, the concept of maturity refers to perfection or completeness of the capability development processes (Wendler, 2012; Facchini *et al.*, 2020). Furthermore, maturity levels define the different stages and compile the elements of capabilities to continuous improvement (Siviy *et al.*, 2007; CMMI Product Team, 2010). Identifying the current stage of maturities is generally called maturity assessment.

Maturity assessment is commonly applied in organizational contexts (Siviy *et al.*, 2007, Stoiber *et al.*, 2023; Poeppelbuss *et al.*, 2011), but it can also be exploited in interorganizational systems and at a sector level (Frick *et al.*, 2013; Seidel-Sterznik *et al.*, 2018; Srai *et al.*, 2013). Motives for deploying sector level maturity assessment include identifying areas of improvements, research results sharing, administration and future strategies facilitation, data management streamlining, knowledge sharing and communication improvements, identifying potential practical applications, inter-company benchmarking and checking the progress (Seidel-Sterzik *et al.*, 2018; Srai *et al.*, 2013). Sector level applications have been developed for, for example, assessing performance of smart city, Life Cycle Management and low-carbon city practices (Wei *et al.*, 2019; Seidel-Sterzik *et al.*, 2018; Shen *et al.*, 2021). A sector level maturity assessment should be simple enough to attract the target audience and produce valid assessment results, but not too simple to overlook vital aspects (Frick *et al.*, 2013).

Maturity models offer a framework for maturity assessment. Maturity models are management tools that can be used especially for assessing strengths and weaknesses of capabilities, derive prioritization and roadmaps for improvements and evaluating and supporting the development of capabilities and processes (Stoiber *et al.*, 2023; Santos *et al.*, 2021; Wendler, 2012; Poeppelbuss, 2011; de Bruin *et al.*, 2005). This paper adapts the CMMI to examine and identify the enablers of improving productivity. The concept of CMMI was originally released for process improvement in 2000 and was developed based on capability maturity models (CMMs) for software and systems engineering and integrated product development (CMMI Product Team, 2010). Today, the concept is widely known and adapted, for example in systems engineering, integrated teams, project management, risk management and acquisition domains (Siviy *et al.*, 2007; Ariffin and Ahmad, 2021; Wendler, 2012). CMMI contains maturity levels and KPAs that serve in identifying the current state, and in some applications, differences between the process areas. The KPAs are different aspects for assessing maturity, and together they form the combination of the process development entity (Siviy *et al.*, 2007). The evolution, structure and different applications of capability maturity models are introduced in several publications (see for example Siviy *et al.*, 2007; Ariffin and Ahmad, 2021; CMMI Product Team, 2010). Exploiting CMMI in specific field of interest requires professional judgment and interpretation of the context (CMMI Product Team, 2010; Wendler, 2012).

3. Research methods

Qualitative method was selected as an appropriate research strategy since the CMMI is a new approach from the Finnish infrastructure sector productivity development viewpoint. The study was performed by adapting an analytical process of CMMI research literature. This included model construction based on literature, content production based on interview data and model validation based on an expert panel. The phases for developing a capability maturity model (integration) have been pictured for example by de Bruin *et al.* (2005), Stoiber *et al.* (2023), Wendler (2012), Munir *et al.* (2020) and Shen *et al.* (2021). The phases are shown in Figure 1.

This paper adopted the first four phases of the process with a qualitative research approach. The *planning phase* is introduced as the analytical process in section 3.1 and *phases 2–4* accordingly in sections 3.2-3.4.

3.1 Analytical process

The scope of this study was to develop a CMMI framework to support the productivity development in the infrastructure sector. Thereby, the aim was to answer the research

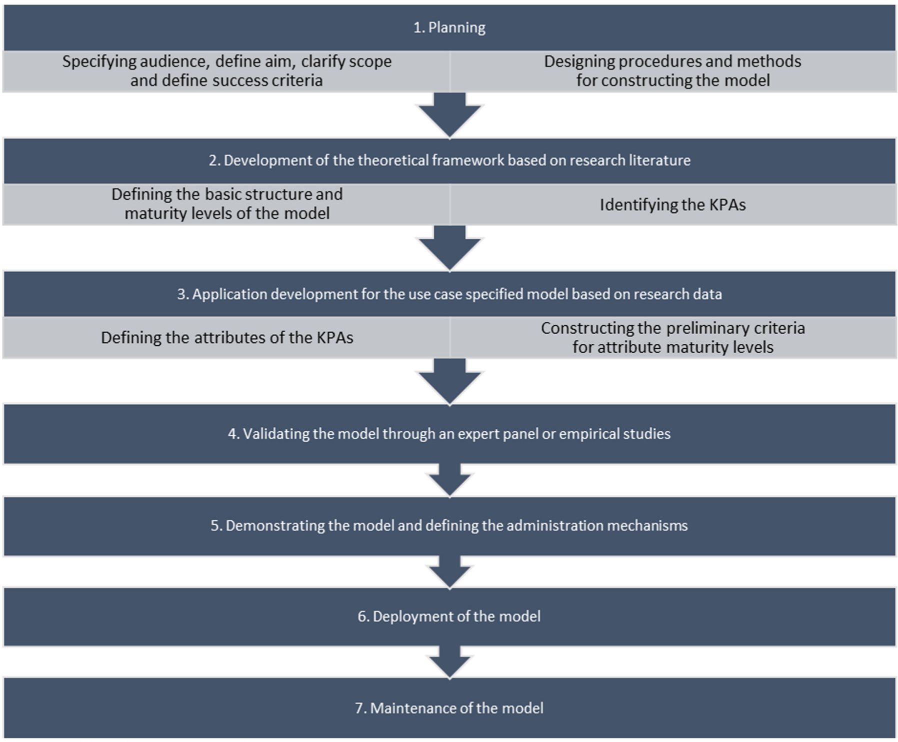

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Figure 1. The general phases of developing a capability maturity model (integration)

question – *What kind of a capability maturity model can help in identifying the enablers of productivity development in the infrastructure sector in Finland?* – by providing a new perspective to understanding the productivity development capabilities through maturity levels and KPAs.

The study was structured in 3 steps presented in Figure 2. First, a general framework of the maturity model for productivity development was constructed based on research literature. Second, the model was fitted into infrastructure sector by utilizing interview data. Third, the model was validated and refined with an expert panel. Through these steps the research ended up with a deployable model (cf. Figure 1 phases 1–4).

3.2 Developing the theoretical framework

Maturity models consist of two common components: (1) a set of levels or stages defining maturities and (2) measured objects (Wendler, 2012). In this paper, the first component is called maturity levels and the second is called KPAs.

CMMI maturity levels create a picture at one end of the unevolved state, and at the other end, the ideal state (Siviy *et al.*, 2007; CMMI Product Team, 2010). In other words, the maturity levels define how deeply implemented the development processes are and how advanced the capabilities to continuous improvement are (Siviy *et al.*, 2007; Ariffin and Ahmad, 2021). In

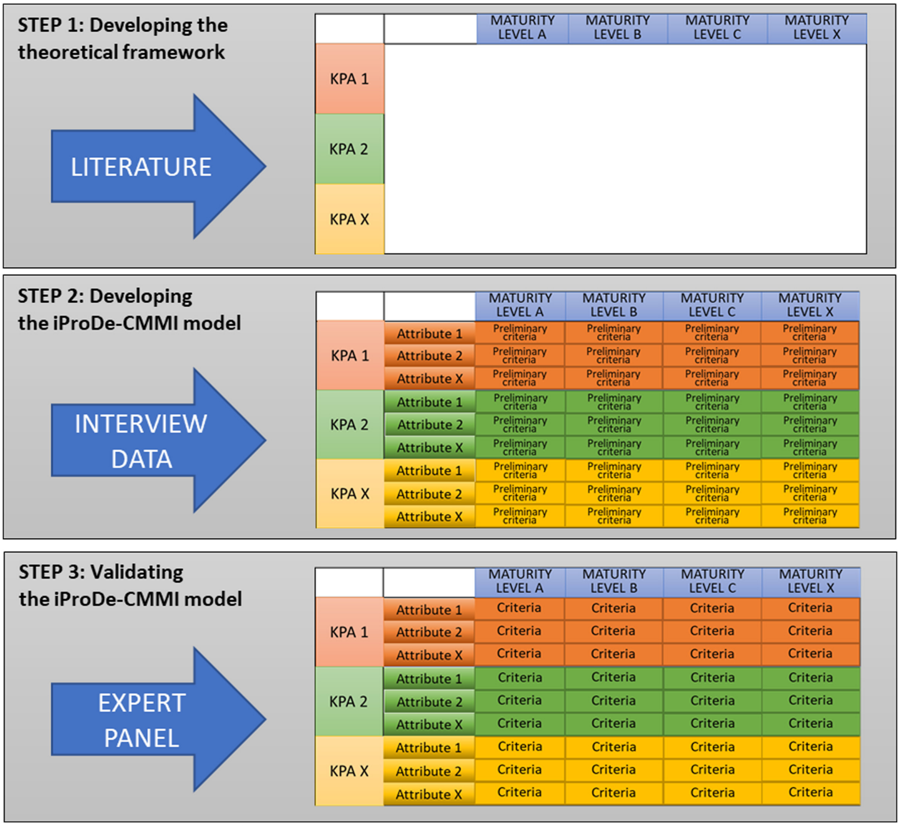

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Figure 2.
Steps and methods of the analytical process

this paper, the general maturity levels were developed through examining and applying previous research literature concerning CMMI applications and reflecting them through an infrastructure sector productivity development capability approach.

The KPAs' were approached as the focal capabilities of development. Since improving productivity requires change, understanding change management is essential. In this paper, the CMMI concept was adapted by treating the "change management elements" as KPAs. Change is, however, anything but simple. For example, organizational changes have fairly high failure rates, with over half failing (Errida and Lotfi, 2021). Nevertheless, there are several models for change management that aim to reduce the risk of failure. One solution is to examine the elements that make the change successful. If one or more elements are lacking, change will likely fail. In addition, maturity models should acknowledge areas that combine to form the basis for achieving the set goals (Siviy *et al.*, 2007).

3.3 Generating the attributes and maturity criteria based on interview data

Since exploiting CMMI convincingly requires professional judgment and interpretation of the context (CMMI Product Team, 2010), the levels are described from the infrastructure sector productivity viewpoint, based on the infrastructure sector representatives' interview data. The maturities of the KPAs can be assessed based on the maturity level descriptions.

The research data was collected through 12 semi-structured face-to-face group interviews (Table 1). The interviews were organized by directly contacting some of the largest organizations in the Finnish infrastructure sector. Interviewees were either the persons contacted or selected by the organizations themselves. Altogether the interviews involved 45 interviewees from different positions, organizations and operations in the Finnish infrastructure sector. The interviews were a part of larger research aiming to form a roadmap to more productive infrastructure sector in Finland and to identify the opportunities and present state of digitalization within the sector and, in this vein, avenues for future research. Thus, the interviews' original purpose is similar to the purpose of this study and adapt the same change management elements as themes that this paper utilizes as KPAs. For this paper, the research data was analyzed from the aspect of enabling productivity improvement in the infrastructure sector. The interview questions are presented in Appendix. As semi-structured interviews, the data consists of richer discussion and broader perspectives than the interview outline presents.

Infrastructure sector specific attributes and preliminary maturity criteria for KPAs‘ were formed through an interview data content analysis. The interview data analysis consisted of seven steps:

(1) Notion composing: identifying enablers and hindrances from the littered interview data

(2) Initial coding: naming basic categories for all notions (enabler/hindrance, interview number, KPAs of change management)

(3) Complementary coding: identifying arising enabler subject areas and naming them + coding the notions along with the complementary categories

(4) Review and revision of the coding structure: assessing the suitability of the coding structure against credibility, applicability and explanatory power of the results

(5) Forming the final coding structure: grouping enabler categories and notions by main themes into 2–3 preliminary attributes per KPA

(6) Arranging the notions inside each attribute according to general maturity level features

Interview ID	No. people interviewed	Duration of the interview	Organization types	Positions	Substance areas	No. units of data
1	2	1 h 40 min	Research	Development	Project delivery models	64
2	2	1 h 30 min	Companies (construction, engineering)	Management, development	BIM	53
3	3	1 h 30 min	Ministry	Specialists	Traffic infrastructure governance, economics and impact analysis	47
4	4	1 h 30 min	National agency and regional agency	Management, development	Infrastructure projects, BIM, customer service and permitting	50
5	4	1 h 20 min	Ministry	Management, specialists	Land use planning and built environment governance	71
6	1	1 h 30 min	National agency	Project management	Infrastructure projects	49
7	2	1 h 30 min	National agency	Management, development	Traffic systems and safety	39
8	18*	1 h	National agency, companies (construction, engineering, it)	Project management, workers, supervision	Project delivery models, infrastructure projects, software and data management, BIM	33
9	3	2 h 10 min	Companies (maintenance, consultancy)	Supervision	Road maintenance	77
10	2	2 h	Company (construction)	Project management, development	Infrastructure projects	14
11	3	2 h	National agency	Management	Asset management, software and data management, BIM	82
12	1	1 h 30 min	National agency	Development	Asset management	65

Note(s): *Interview was integrated in a collaboration meeting between two major development projects
Source(s): Table by authors

Table 1.
Basic information from the interviews

(7) Forming the preliminary criteria for attribute maturity levels

3.4 Validating the model through an expert panel

An expert panel was executed to validate and get insight into comprehensibility, suitability and applicability of the constructed model. The members of the panel were selected from experts that have a strong multidisciplinary experience and approach regarding to infrastructure sector.

The panel consisted of 5 experts representing different aspects and operations of the sector:

(1) Expert A: Municipality traffic designer with versatile experience from consultancy, team management and different planning levels as well as integration of different technical fields. 20 years of working experience in the infrastructure sector.

(2) Expert B: Leading consultant in infrastructure digitalization consulting company with over 30 years of extensive experience in cities' land use planning processes, technological solutions development and managerial roles.

(3) Expert C: Leading expert in Urban Environment Division of a city. Over 10 years of wide municipal and consultancy experience from project leadership of large projects, team lead and development, asset management and traffic planning.

(4) Expert D: Head of Permits in a national agency with over 10 years of deep experience of operational, tactical and strategic work in permitting processes, logistics and collaboration networks.

(5) Expert E: Development Manager of services in company offering site management solutions. Nearly 30 years of extensive experience from construction and maintenance works.

The success of a model is determined in accordance with comprehensibility, suitability and applicability of the model in the deployment scope viewpoint (de Bruin *et al.*, 2005; Frick *et al.*, 2013; Stoiber *et al.*, 2023). The expert panel validated the model through two questions:

(1) Is the criteria of attribute maturities comprehensible and suitable? How should it be refined?

(2) On which prerequisites would the presented model be applicable in the Finnish infrastructure sector?

4. Results and discussion

This section presents the main findings from the research question. First, the developed theoretical framework is presented. Second, there is an exploration of the attributes and maturity criteria of the KPAs based on the interview representatives' conceptions to perceive the enablers of infrastructure sector productivity development. After that, the validation results of the expert panel are presented. Consequently, this section ends up answering the research question by introducing the model for infrastructure Productivity Development CMMI named iProDe-CMMI-model.

4.1 Theoretical framework for the model

In this paper, productivity development is approached as a continuous pursuit for improvement. Continuous improvement is considered as a systematic development process instead of discrete development projects or programs. Therefore, the existence and operability of development processes is seen as a key to examining the current situation and improvement capabilities. On the other hand, infrastructure sector level productivity improvement requires total optimization. Decisions regarding the application of a CMMI model adapted from De Bruin *et al.* (2005) are as follows:

(1) Audience: Internal infrastructure sector audience of executives and management. Use case is to identify and put into practice how the sector's productivity can be developed through identifying and improving productivity development capabilities.

(2) Method of application: self-assessment or third party assisted. Application means could be for example a barometer for sector representatives or action research executed by researchers.

(3) Internal driver of application and requirements: More efficient usage of budget, profitable business, more fluent workflow to ease the burden of loaded workers.

(4) External driver of application and requirements: Securing the infrastructure system that serves the citizen and industrial life sustainably with a proper service level.

(5) Application method: Infrastructure sector as one entity, possibly sub-system-specific sub-entities.

The characteristics for productivity development capability maturities are (applied from Thomas and Saleeshya, 2021, Facchini *et al.*, 2020; Santos, 2021; Wei *et al.*, 2019, Donellan *et al.*, 2011):

(1) *Initial:* Productivity development and KPA activities are partially performed, unpredictable, cannot be managed or controlled, difficult to withstand times of stress. Only a few processes are well defined and the success of the projects depends on individual initiative. Infrastructure sector workers have poor understanding of the productivity development concept.

(2) *Defining:* There is a limited productivity development strategy with associated execution plans. Productivity development largely reactive and lacks consistency. There's an increasing awareness of the subject, but accountability isn't clearly established. Some policies might exist but are adopted inconsistently. The main productivity development processes are generally well planned, defined, to control their cost, time and functions. Process results are reproducible.

(3) *Adopting:* Properly documented, standardized and tailor-made productivity development processes, tools and standards. Capabilities and skills are developed to contribute to productivity development. Productivity development operations are managed by common procedures and standards.

(4) *Integrated and adaptive:* Productivity development is a core component of the infrastructure sector activities and fully integrated into processes. Detailed information regarding productivity bottle necks is systematically collected and analyzed for each process. Abilities and awareness of need for solving conflicts based on situational awareness and productivity targets. Activities are aligned to meet internal and external needs.

(5) *Dynamic and agile:* Systemic and strategic integration of productivity development, in which continuous process improvement is a natural part of the work and creates a platform for innovations. Situational awareness is systematically generated and strategy implementation is aimed efficiently to practical work gripping points. The workers are constantly actively learning and deploying new productivity development knowledge and skills.

The characteristics of the levels are adopted from the CMMI model, and it describes the maturity of the development processes.

4.1.1 Identifying KPAs. According to Knoster (2000), five elements (cf. "KPAs") are required to successfully make a change: (1) vision, (2) skills, (3) incentives, (4) resources, (5) action plan (Errida and Lotfi, 2021). While the five elements of successful change presented by Knoster (2000) include an extensive range of foundations for successful change, some shortages were identified. First, “abilities” was added as a complementary element to skills. Second, fluent collaboration is vital for successful change in a multi-organizational multilevel environment such as the infrastructure sector, and thus, “collaboration” was included as an independent element. Furthermore, although incentives are an essential motivation creator, the required processes should be examined when implementing change. Hence, instead of examining incentives alone, “incentives” is examined with “processes”. Lastly, since technology is getting a great deal of attention in development initiatives and programs (cf. Wiren *et al.*, 2019), “technology” was separated from “resources”. This provides the following KPAs: (A) vision, (B) skills and abilities, (C) collaboration, (D) processes and incentives, (E) technology, (F) resources and (G) action plan.

4.2 Input of the attributes and maturity criteria: focal enablers of productivity improvement

While literature provided the KPAs, the KPA attributes and their maturity criteria were derived from interviews to provide professional judgment and interpretation of the context. Each KPA gained 2 or 3 attributes. Altogether 18 attributes were formed. They reflect the interview discussions on challenges and development needs, which provide the enablers of productivity improvement. In the following, each KPA’s attributes, and their maturity characteristics, are presented.

4.2.1 Vision (A). Situational awareness: Situational awareness means the social and technical evaluation of the situation in relation to the intended vision. Low maturity is characterized by having no common understanding of the big picture, while high maturity is described by having continuously refining socio-technical organization focused on the tracking of the situation. The big picture should be formed in co-operation with the stakeholders, and the role of the government is crucial.

> The big picture should be formed together with companies and public sector. (I7)
>
> Government must be conscious of sectors’ development needs regarding practical work. (I5)
>
> The most important enablers of vision are organization, management systems and monitoring. (I4)

Budget: Current budgeting arrangements provide challenges for infrastructure sector activities. The arrangements need to be steered more towards practice needs’ perspectives. Yearly budget-based arrangement does not have space for long-range optimization (I3) which other interviewees see leading to “conventional solutions” (I12), “difficulties in productivity development” (I4) and “short-range asset management” (I9). Low maturity systems prefer yearly cost prioritization over practice development, while high maturity systems prefer emphasizing long-term perspective.

> The sector should be aiming at lifecycle effective steering models. (I12)
>
> Construction projects should be better harmonized to maintenance. (I4)
>
> It is important to focus on cost-benefit analysis to create public value as we must see which todays’ investments bring savings in the future. (I7)

Regulation: The data suggests that “*laws and Instructions either challenge or support productivity development*” (I3). Experts view that “*political level can cultivate digitalization and productivity*” (I7) if “*organization and field would not be scattered in the governmental level*” (I4). Thus, low maturity is characterized by fragmentation and conflicts with productivity development, whereas high maturity is described nurturing relationship between regulation and productivity development.

4.2.2 Skills and abilities (B). Infrastructure lifecycle and information management: Single individuals are said to have extensive influence in the sector (I11) and different responsibilities are unbalanced or fragmentary (I1; I2; I5; I6; I11). In addition, experts recognize that there is a lack of key competences (I2; I6; I10; I11) and organizational and personnel changes confuse development efforts (I5; I6).

> Knowledge and decision grounds should be carried through the process. (I1)
>
> The sector needs a habit of situational check-ups. (I11)
>
> Individuals' ability of recognizing their own role and information exchange needs should be strengthened. (I8; I11).

It is recognized that perceiving the essence of infrastructure sector takes a lot of effort (I1; I9) and requires "lifecycle-thinking" (I12), "know-how on digitalization" (I10), "identification and empowerment of key roles" (I4; I9; I11) and comprehension of physical, social and timely structure and relations of infrastructure (I3; I5; I9; I11). Here, low maturity appears as fragmented and unclear roles and responsibilities combined with influential single individuals, while high maturity systems focus on utilization of situational awareness built around lifecycle-thinking and empowerment of key individuals in specific decision-making situations.

Procurement effectiveness: Experts recognize that clients' procurement abilities are lacking (I2; I5; I9) and that procurement can be usually characterized as "*fulfilling formal standards*" (I1). Procurement would benefit from public actors and asset owners, taking a stronger ownership mentality regarding infrastructure and productivity development (I2; I7; I9). This could be executed through flexible utilization of procurement models (I1; I7; I11) and through practical monitoring of operations (I6) which would ensure that quality (I1; I5; I9), information (I9; I6; I5), situational awareness (I6; I9; I11; I12) and innovation requirements (I1; I2) steer the project execution genuinely. Thus, low maturity is characterized by conventional practices in procurement, whereas in high maturity system, client-owner has comprehensive understanding of the infrastructure system which enables procurement of value creating products and services while utilizing accurate operational indicators.

> The consultant (designer) doesn't even know what kind of data and information the customer needs. The customer must be able to define what information is needed, in what form and where the information should be stored. (I2)

Education as a tool for implementing continuous improvement: Some experts consider that graduates have lacking work life skills (I6) and infrastructure and information management training (I3; I9), while digital skills and new instructions take time to put into practice amongst workers (I2; I9). Data suggests that developing the university level education to respond to infrastructure sector needs (I3; I5; I9) and "*increasing practical work experiences*" (I6) through "*master-apprentice model*" (I12) can advance both "*graduates introduction to substance matters*" (I6) and "*multi-professional updating to the education of workers*" (I3). Here, low maturity is characterized by disparity between education and work-life practices, while high maturity education works in tandem with work-life organizations and both supplement each other.

4.2.3 Collaboration (C). Operating model in procurement for crossing siloes through commitment: Experts perceive that effective commitment and stakeholder engagement are keys to enabling functional solutions and fluent workflow (I1, I2, I6, I8, I9) while collaboration and ground rules enable the understanding of needs of others (I1; I2; I5; I8). It is considered that contract models either limit or support collaboration (I2; I4). Most important practices to enhance collaboration in procurement are "early and preventive risk management" (I1), planning, innovating and doing actual work together (I5; I11), "enriching existing knowledge with new information" (I12) and "including wider development as a part of project execution" (I5). Thus, in low maturity procurement contracts, managerial practices and lack of common understanding impede collaboration by fostering sub-optimization, whereas in high maturity procurement, contracts and management serve to facilitate collaboration to achieve appropriate outcomes.

> It is necessary to identify the strengths of different procurement models in order to utilize those strengths in other procurement models. (I4)

Collaboration networks and ecosystems: It has been experienced that organizationally independent development efforts are inefficient to solve sector wide challenges (I1; I5; I7), whereas "large actors together can signpost the development direction" (I3; I4). "Key elements of successful collaboration are continuous improvement and development" (I4) as well as "ensuring adequate decision-making powers" (I5) and "engaging stakeholders" (I1; I3). Sharing of experiences, copying and scaling functional practices are needed (I4; I5; I7; I11; I12) and can be realized through setting up agile collaboration ecosystems and practices (I4; I5) and/or by "utilizing existing structures" (I1). Here, low maturity systems have limited collaboration structures, while high maturity systems utilize multiple actors broadly through the field to continuously improve the whole industry.

> The participation of different stakeholders, clear roles and cooperation models are the key to successful cooperation. Reaching the goal requires that everyone understands the process by which the goal is reached. (I3)

> Good cooperation requires good leadership and continuous improvement and development. (I4)

4.2.4 Processes and incentives (D). Infrastructure lifecycle productivity management: Through the interview data it can be inferred that "*system optimization*" (I3), "lifecycle simulations" (I11; I12), "investigation of effective measure" (I12) and continuous improvement in information management and exchange routines (I4; I11) can solve lifecycle inefficiencies (I6; I9) and extra work (I5) caused by heterogeneous practices and targets between different actors (I4; I5; I6; I7; I9; I11) and slow and laborious permit and acceptance processes (I1; I5; I10; I11). Here, low maturity systems' operations are performed as separate lifecycle phases with little connection to the whole, while high maturity is characterized by lifecycle perspective and versatile data management.

> Life cycle thinking is needed. The needs of the following stages should be better taken into account in the earlier stages. Life cycle costs should also be taken into account in addition to investment costs. (I12)

> Information management and information exchange in different phases of the infrastructure life cycle is a big problem. (I6)

Procurement as a core to value creation: Data suggests that procurement projects should contain "*early dialogue*" (I2), "*effect simulation*" (I5) and "*project specific situational awareness and execution milestones*" (I6). This could be enabled by "*identifying project model independent success factors*" (I6) and developing "*lifecycle piercing feedback loops*" (I9) and "*contracts that encourage openness and contain beneficial compensation models*" (I6). Low maturity is characterized by sub-optimization with little collaborative dialogue, while high maturity procurement highlights openness and collaboration with focus on project specific goals.

Operating models empowering effectiveness: Through the data it can be inferred that finding collective incentives bring good results (I3; I5) regarding feeling of rush (I5; I11) and to the "*lack and difficulties of commitment*" (I4). Enablers for "*eliminating unnecessary work stages*" (I11) are "*detecting and describing core processes*" (I11) with "*solving the bottle necks of practical work*" (I5), "*improving communication and information exploitation*" (I7; I11), "*regular status meetings*" (I6) and "*schedule management*" (I8). Low maturity is characterized by feeling of rush and lacking incentives, whereas high maturity is described by effective schedule and target management with fluent decision-making.

4.2.5 Technology (E). Technological solutions: Current technologies are commonly expired (I1; I2), overlapping (I2; I4; I10), fragmented (I4) and closed (I1; I5), which makes data collection laborious (I2; I5; I7; I8). Technological solutions development capability can be improved through "*making data independent of applications*" (I1); "*shared ICT-development projects*" (I1); "*embracing modular structures*" (I11) and "*better consideration of the end user*" (I2). Low maturity technology is old and enclosed systems disrupt collaboration and development, while high maturity technology solutions enable tailoring to specific needs and foster continuous improvement and supports practical processes.

Information management and data structure: Interview data considers that "*clarifying information management means in productivity development is needed*" (I1) and it can be enabled by standardization of information structures (I1; I2; I5; I6), common terminology (I1; I2; I6) and "*object libraries*" (I6). Low maturity information management and data structure is difficult to utilize widely and is very vulnerable to organizational changes and disruptions, whereas high maturity systems have shared structures which enables common understanding, forecasting and development of automatization.

> Digitalization should support the core activities. (I11)

> Information management should be arranged so, that organizational changes don't disrupt development. (I11)

Interoperability: Data suggests that effective information transfer between different parties can be enabled with "*constructing the data foundation from the lifecycle perspective*" (I12), "*identifying and enhancing the core functions*" (I7), "*finding solutions to fit the existing information together with the new*" (I5; I6) and "*utilizing and improving the possibilities of data transfer*" (I3). Low maturity systems have information stored in individual folders and are hard to find, whereas in high maturity systems data transfer is two-way which enables feedback and continuous improvement.

4.2.6 Resources (F). Resource planning and coordination: Experts consider that there is a lack of skilled experts and monetary resources for productivity development (I3; I4; I6; I8; I9; I11) due to "*retirement*" (I8) and because "*digitalization related development resources lie in different ministries and government agencies*" (I4).

> Resource givers don't always understand the development resource needs. (I4)

> The leading role should be pointed to the actor that perceives extensive processes and courses of action and has sufficient resources. (I11)

In low maturity systems the lack of skilled experts hinders the proceeding of productivity development initiatives, while high maturity systems allocate and enable resources for continuous development work through organized actor network.

Development resource integration: It is seen that "*parties are resistant to bringing ideas to other activities and want to keep their resources in their own profitable operations*" (I1). However, "*lifecycle resource efficiency can be achieved with modest development contribution in practical activities*" (I3). It is suggested, that "*monitoring of predictive actions as well as lifecycle related feedback should be included in the working methods*" (I9). Low maturity is characterized by development resources' separation from practical work and other organizations, whereas high maturity systems consider productivity development as a natural element of practical work.

4.2.7 Action plan (G). Effective implementation: Data considers that agreements, visions and roadmaps only create development if they are followed in practice (I1; I4; I5; I7; I9; I11). However, determined silo piercing can be realized by mapping out the future together (I7; I11)

> Development often gets frozen or faded due to organizational changes. (I7)
>
> Sector-wide productivity development is slow and demands persistent implementation efforts. (I12)
>
> People and change leadership should be consciously kept in mind while driving development. (I2)

Productivity development process should contain activities of "*generating and deploying maturity models*" (I12), "*representing target levels*" (I11), "*putting annual calendar into operation*" (I11), deployment support and active implementation (I4; I5; I11; I12), working out situational pictures (I1; I12) and monitoring progress through indicators (I4; I8; I11; I12). Low maturity is characterized by productivity development initiatives getting frozen or faded due to lack of continuity, whereas high maturity systems' determined productivity development implementation acts as a catalyst for innovation and collaboration accelerating productivity development of the whole sector.

Silo crossing situational awareness-based budgeting: Experts consider that public funding prompts piloting, but wider mobilization of development requires that development is integrated to practical work (I2; I3; I11). This is seen to require "*financial motivating of parties via procurement practices*" (I5), which can be seen to mean that "*general infrastructure productivity development should take part in project budgeting*" (I3). Low maturity systems' innovations are typically outlined from projects due to strict yearly budgets, whereas high maturity systems' continuous infrastructure productivity development funding creates a platform for more effective development funding methods.

4.3 Validation outcomes of the expert panel

The iProDe-CMMI-model was validated through an expert panel, which considered the model comprehensible, well-structured and applicable to infrastructure sector. Yet, Expert E argued that "*the model is quite abstract and requires examples of practical applications to support the understanding on how one can advantage it in one's own work*". Some participants felt that the content is very extensive. One participant suggested breaking the model down to comprehensible entities and another considered whether the content should be simplified.

In addition to sector level deployment, the panel found potential and interest in exploiting it in organizational assessment. The panel saw high importance in raising discussion in the sector upon the iProDe-CMMI KPA attributes and criteria to enable productivity development. The experts agreed that the model supports the linkage between strategic and operative level.

> Dialogue between high-level strategies and details of the practical work is certainly needed. Further, understanding of core processes, tasks and required skills in different fields, levels and phases is essential. Solving bottle necks of practical work should be aligned with broader strategies. Infrastructure projects contain several different perspectives and phases, that might be contradictory. Awareness of these contradictions makes it possible to achieve a successful outcome. On the other hand, sometimes it is critical to accomplish the work fast and all the optimal information might not be on hand quick enough. These kinds of acute situations would benefit from pre-organized support and steering structures. The ability of identifying uncertainties, asking the right questions, and assessing the situation might be even more important than the abilities of solving certain technical matters. (Expert A)
>
> The model provides some targets that challenge current business logics, which is certainly valuable and induces discourse. (Expert B)

All of the expert panel participants indicated, that the KPA criteria illustrate the infrastructure sector well and is comprehensible. The expert panel offered also a few detailed ideas for refining the criteria related to highlighting the understanding of lifecycle piercing information needs, knowledge transfer structures compensating the challenges of organizational changes, contract's spirit in project management, feedback from projects to procurement development, processes ensuring proper preparation before processing, need of silo-specific terminology in addition to the common terminology and money and time investments needed for productivity development actions.

4.4 iProDe-CMMI-model for examining the infrastructure sector's capabilities for productivity development and discussion

Table 2 presents the final refined infrastructure productivity development (iProDe) CMMI-model. The final model integrates the literature framing on CMMI model and change management, while utilizing the professional judgment and interpretation of the context from interviews and considerations of the expert panel.

The general phases of developing a CMMI-model are presented in Figure 1. According to them, adapting and advantaging the iProDe-CMMI-model requires demonstrating the model and defining the administration mechanisms, deployment of the model and maintenance of the model. Demonstration and deployment of the model are suggested to be carried out by:

(1) Analyzing the current maturity levels of all KPA attributes.

(2) Identifying the attributes and KPAs with lowest maturity.

(3) Mapping the enablers of productivity development that are activities needed to (1) improve the maturity of the attributes with lowest maturity, (2) embrace the attributes that inspire the overall productivity development and, (3) prevent the attributes from falling on lower maturity level.

(4) Enforcing the identified enablers of productivity development.

(5) Repeating the steps 1–4 with an appropriate cycle.

This paper answers the research question: "*What kind of a capability maturity model can help in identifying the enablers of productivity development in the infrastructure sector in Finland?*" Previous development work related to infrastructure sector productivity has focused on limited targets and they are often executed from the perspective of an organization's top management, which has formed an incoherent and mind-bending view to the practical work focusing on projects (e.g. Aziz *et al.*, 2017; Götz *et al.*, 2020; Lee *et al.*, 2015; Munir *et al.*, 2020). Instead, the model introduced in this paper offers a perspective of productivity development capabilities, infrastructure system and lifecycle. The model challenges current business logics by suggesting that reaching a more mature level on productivity development capabilities requires an open alignment of the internal and external incentives (cf. *goal incongruence* in Johanson and Vakkuri, 2017) and a strong integration of education and development into practical work.

The study shows that the CMMI offers an adaptable framework for examining the capabilities as the enablers of productivity development in the infrastructure sector. This is supported by Srai *et al.* (2013), who indicate that CMMI has been utilized in interorganizational context successfully before and here this appliance is continued through infrastructure sector perspective. The enablers arisen from the interview data bring important topics to discuss to enable the productivity development. The suggested attributes and maturity level criteria form a basis for further examination of the sector's current situation and development targets. Yet, the enablers, attributes and maturity level criteria should be considered as a starting point and future studies should contain an assessment of improvement needs of the model. In conclusion, this paper adopts the CMMI approach and presents a novel iProDe-CMMI-model for examining and improving productivity development capabilities in the infrastructure sector.

Table 2. iProDe-CMMI key process areas, attributes and maturity criteria

Key process area (KPA)	Indicator attribute		Maturity criteria
KPA A: vision	Situational awareness	1	*Initial:* No big picture
		2	*Defining:* Limited groups of people have big pictures of exclusive settings
		3	*Adopting:* Sector vision of productivity development
		4	*Integrated and adaptive:* Administration acknowledges the development needs of practical work and sets common goals aiming to solve them
		5	*Dynamic and agile:* Infrastructure productivity development strategy is deployed and regularly refined through organization, management systems and productivity development indicators
	Budget	1	*Initial:* Yearly budget steers to cost prioritization over development
		2	*Defining:* Budget for individual pilots
		3	*Adopting:* Flexible budget for testing new models in daily operations
		4	*Integrated and adaptive:* Indicated impacts of tested and developed solutions bring input for productivity development budgeting
		5	*Dynamic and agile:* Lifecycle efficient solutions implementation is a natural part of budgeting and creates a basis to innovating more efficient budgeting procedures
	Regulation	1	*Initial:* Infrastructure regulation scattered. Data exploitation licenses unclear
		2	*Defining:* Government policy includes infrastructure productivity development. Sector governance is organized
		3	*Adopting:* Laws and instructions steer desired practices, technological principles and information sharing
		4	*Integrated and adaptive:* Regulation supports efficient operation models, process development and knowledge production
		5	*Dynamic and agile:* Regulation and productivity development nurture each other
KPA B: skills and abilities	Infrastructure lifecycle and information management	1	*Initial:* Roles and responsibilities related to lifecycle and information management are unclear. Individuals have a significant influence on development focus and continuity
		2	*Defining:* Lifecycle and information management are often appointed as requirements, but responsibilities and authorities are unbalanced. Decision procedures are difficult and prolonged. Common structure and body of core matters is lacking. Certain key skills appear as bottle necks for performance and producing recoverable outputs
		3	*Adopting:* Focal roles and concepts for crossing siloes are identified, yet lifecycle and information management are developed separately from each other. Instructions and requirements exist. Applying abilities might be insufficient
		4	*Integrated and adaptive:* Lifecycle-thinking is integrated to information management. Ownership of development is assigned. Lifecycle-thinking brings requirements that align the limited targets and lifecycle information needs
		5	*Dynamic and agile:* Lifecycle-thinking and knowledge management practices conduct to continuous improvement of efficient operation models, methods and tools. Situational awareness on infrastructure system acts as a basis for common understanding and situational decision-making abilities and empowerment of key individuals

(*continued*)

Table 2.

Key process area (KPA)	Indicator attribute		Maturity criteria
	Procurement effectiveness	1	*Initial:* Procurement skills particularly related to technology are insufficient and vendor-locks evolve easily. Markets adopt new operational models slowly
		2	*Defining:* Projects are initiated with inadequate grounds. Procurement contains requirements for information outputs on a general level. Experienced buyers are competent in applying traditional contract models
		3	*Adopting:* Special technologies are demanded and formally met but might not serve infrastructure lifecycle management needs
		4	*Integrated and adaptive:* Different procurement and contract models are advantaged conveniently. Customer understands digital principles and productivity development methods. Experts can be utilized flexibly to ensure quality and lifecycle productivity. Results and outputs are produced and integrated smoothly into the infrastructure system entity
		5	*Dynamic and agile:* Buyer has a comprehensive understanding of infrastructure system and ability to buy value creating products and services. Operational indicators and interpretation skills support the steering of projects. Requirements and continuous improvement culture support the development of know-how in assignments
	Education as a tool for implementing continuous improvement	1	*Initial:* Processes are performed in traditional practices mostly separately from education. Graduates lack working life abilities and university level education corresponds insufficiently to infrastructure sector needs
		2	*Defining:* Infrastructure sector development skills are occasionally added to education programs. Instructions to modern practices exist but understanding and implementation to practical work is inadequate
		3	*Adopting:* Education contains practical training. Development projects aiming to ability improvement are driven, but often lacking substance knowledge and separate from general training and education
		4	*Integrated and adaptive:* Education and training are oriented to respond to infrastructure sectors' administrative and practical needs. Modern technological skills of students and graduates are fluently combined with substance knowledge and experience of senior employees
		5	*Dynamic and agile:* Educational and work life training collaboration is business as usual and forms a platform for both education development and work life skills continuous improvement
KPA C: collaboration	Operating model in procurement for crossing siloes through commitment	1	*Initial:* Contracts, managerial commands and lack of common language impede collaboration
		2	*Defining:* Ground rules and contracts support collaboration between direct parties. Success depends heavily on individual abilities
		3	*Adopting:* Early involvement of different parties enable operative solutions and information transfer throughout the lifecycle
		4	*Integrated and adaptive:* Engaging processes and mechanisms enhance risk management, trust, opportunity recognition and spirit of success
		5	*Dynamic and agile:* Functional development concepts identification and utilization is a natural part of practical work and projects

(*continued*)

Key process area (KPA)	Indicator attribute		Maturity criteria
	Collaboration networks and ecosystems	1	*Initial:* Collaboration structures ambiguous, organizational renewals disrupt initial collaboration networks
		2	*Defining:* Methods differ between parties, individual central associations are messengers
		3	*Adopting:* Networks bring actors together and enable experience sharing
		4	*Integrated and adaptive:* Public and private sectors participate in generating multi-professional ecosystems to monitor best practices and implement solutions
		5	*Dynamic and agile:* Decision-making powers and continuous improvement culture are key to collaboration networks' agile innovation and development throughout the sector
KPA D: processes and incentives	Infrastructure lifecycle productivity management	1	*Initial:* Operations and processes performed randomly as separate lifecycle phases with individual goals, interests and data. Administrative ad-hoc requests, rush and partial optimization are common
		2	*Defining:* Customary operations don't interact with each other. Insufficient understanding of other parties influences and needs cause distractions and data expiry
		3	*Adopting:* Basic data of properties and condition. Consistent lifecycle and impact assessment calculation methods. Process alignment efforts. Descriptions of asset management systems and generic end user needs
		4	*Integrated and adaptive:* Flexible and efficient processes due to identified and empowered infrastructure lifecycle core processes and efficient knowledge management across siloes
		5	*Dynamic and agile:* Transparency, versatile data management and maturity methods agitate systematic lifecycle productivity development
	Procurement as a core to value creation	1	*Initial:* Case-specific management principles. Requirements and contracts are often argued. Business logics base on work amount instead of value or efficiency. Non-existent feedback
		2	*Defining:* Execution plans are insufficient and formal. Unpreparedness to manage unclear and emerging needs. Outputs don't take end user into account
		3	*Adopting:* Standardized procurement documents. Projects start with collaborative clarification of premises and objectives. Project management feels laborious. Solutions are explored during execution
		4	*Integrated and adaptive:* Agreement supported monitoring of milestones and shared experiences bring project success for both customer and producer
		5	*Dynamic and agile:* Managing schedule, situational awareness, risks and opportunities is business as usual and generates profits and lifecycle cost efficient solutions

(*continued*)

Table 2.

Table 2.

Key process area (KPA)	Indicator attribute		Maturity criteria
	Operating models empowering effectiveness	1	*Initial:* Inefficient meetings, rush leads to waste, conflicts and lack of logic, defect influences accumulate, faint commitment
		2	*Defining:* Unpredictable troubleshooting places development, distorted or vague core processes, time-consuming orientation
		3	*Adopting:* Described and standardized processes and procedures. Strong routines. Changes require heavy reasoning
		4	*Integrated and adaptive:* Reconciliation, monitoring of common interests and regular check-up meetings align self-serving targets with collective goals
		5	*Dynamic and agile:* Schedule and target management, continuous improvement of practical work bottle necks and fluent decision-making enhance workflow development
KPA E: technology	Technological solutions	1	*Initial:* Technology is old and does not respond to practical needs. Enclosed systems cause vendor-locks and block data transfer and development
		2	*Defining:* Infrastructure owners and service providers develop own systems that do not communicate with each other. Different technologies possess different formats and data is bound to the system. IT companies produce products based on general needs
		3	*Adopting:* Common principles of technological development aim to openness and modularity. Interfaces and integrations are typically taken into consideration. Modern features and updates support user needs and data transfer requirements. User might still need multiple applications to execute a task
		4	*Integrated and adaptive:* Enterprise architecture forms a framework for technology development. Data and software are separated, so that modules can be renewed without losing data. User group specific interfaces gather functionalities and views that support and streamline practical processes
		5	*Dynamic and agile:* Workers can easily tailor their interface to respond to personal needs. Automatization helps in identifying bottle necks and reoccurring problems. Involvement in technological continuous development creates a basis for users to innovate and deploy digital solutions to improve their productivity

(*continued*)

Table 2.

Key process area (KPA)	Indicator attribute		Maturity criteria
	Information management and data structure	1	*Initial:* Information management is partially manual and paper based. Data quality is random. Attitudes to information management limit data transfer
		2	*Defining:* Data and information accumulates, but information management is not organized. The present state of infrastructure assets is gathered regularly but established practices for information utilization do not exist. Traditions and efforts in information management development differ considerably and organizational reforms disturb development. Terminologies and data structures are different in siloes
		3	*Adopting:* Information need definitions bring clarity to benefits and costs of organized information management. Data quality and meta data requirements are described. Overlapping terminologies are acknowledged – different names for same things cause confusion
		4	*Integrated and adaptive:* Efficient mechanisms of standardization and information management support common information structures. Information management responsibilities are assigned. Though, infrastructure sector and buildings have different standards and data structures. Information update methods and cycles as well as primary data storages are defined and described. Information is efficiently and systematically collected and exploited. Digitalization is genuinely harnessed to support core processes
		5	*Dynamic and agile:* Infrastructure and construction sector have common terminology for built environment. that bases and contributes to international standards. Terminology, data structures and object libraries are managed in common platform. Information management and structural instructions enable common understanding, forecasting and development of automatization. Unnecessary information is picked out and cleaned. Information management practices enhance infrastructure productivity development innovation and efficiency
	Interoperability	1	*Initial:* Information is often stored in individual folders and hard to find
		2	*Defining:* Shared folders or databases exist for certain data, yet information structures vary. Different processes and operations produce information in a coherent, but silo-specific structure and format
		3	*Adopting:* Different processes produce new data in compatible form, but with different level requirements. Interfaces and data transfer enable data combining from different sources. Old information remains is hard to find or exploit
		4	*Integrated and adaptive:* Lifecycle management needs act as a basis for building the basic information. Detailed information is linked to basic information and accessible with appropriate access management. Also old information is digitized either material based or demand based
		5	*Dynamic and agile:* Data transfer is two-way enabling feedback and quality improvements. Master data, mirroring and other techniques support real-time data updates and usage. Easy data transfer and interoperability creates basis for new innovations

(*continued*)

Table 2.

Key process area (KPA)	Indicator attribute		Maturity criteria
KPA F: resources	Resource planning and coordination	1	*Initial:* Understanding of vital resources varies occasionally. Retirement and lack of special experts hinders the proceeding of productivity development initiatives
		2	*Defining*: Productivity development resources are appointed but lie scattered in different organizations and departments
		3	*Adopting:* Actor network is organized for productivity development. Collaboration is based on meetings and conversations
		4	*Integrated and adaptive:* Benchmark and coordination supports sharing and scaling efficient infrastructure productivity development measures
		5	*Dynamic and agile:* Productivity development work is planned and controlled so that key resources can be utilized efficiently and results are easy to implement in practical work through organized actor network. Continuous development endorses innovations that boost efficient resource usage
	Development resource integration	1	*Initial:* Productivity development resources and initiatives are separated from practical work
		2	*Defining:* Productivity development is executed by development organization. Practical work experts are involved occasionally in defining needs and solutions
		3	*Adopting:* Productivity development organization focuses on developing and introducing practical solutions in collaboration with named practical work experts
		4	*Integrated and adaptive:* Operative feedback loops construct a profitable picture of the proceeding and bottle necks of productivity development measures deployment
		5	*Dynamic and agile:* Productivity development is a natural element of practical work and employees can conceive solutions regarding their own work. Productivity development functions coordinate the feedback entity and development of concentrated development actions
KPA G: action plan	Effective implementation	1	*Initial:* Productivity development initiatives get often frozen or faded due to organizational changes or lack of continuity
		2	*Defining:* Targets for infrastructure productivity development are set and communicated widely. Core processes are pictured, and case studies are executed aiming to identify challenges and needs of practical work
		3	*Adopting:* Roadmap and prioritization for achieving productivity development goals is constructed. Maturity models are a common tool for generating strategies
		4	*Integrated and adaptive:* Maturity level assessment is performed regularly in order to perceive the situational productivity development capabilities. Progress of the roadmap is monitored and productivity development measures are targeted based on infrastructure sector vision, roadmap refinement and current maturity levels. Implementation contains effective tools such as deployment through piloting and coaching. Development actions are targeted to mapped focal points of practical work
		5	*Dynamic and agile:* Determined productivity development implementation acts as a catalyst for innovating collaborative models and implementation methods that accelerate infrastructure productivity development in the whole sector

(*continued*)

Key process area (KPA)	Indicator attribute	Maturity criteria
	Silo crossing situational awareness-based budgeting	1 *Initial:* innovations are typically outlined from projects due to strict yearly budgets 2 *Defining:* Pilots and tests are budgeted and performed 3 Adopting: Infrastructure sector productivity development is included in public administrative programs and a temporary budget for development work is granted 4 *Integrated and adaptive*: Public continuous funding for productivity development initiatives implementations and scaling. Administration acknowledges the needs and bottle necks of practical work, which serves as a basis for targeting funding and measures effectively 5 *Dynamic and agile:* Stable funding structure and effective allocation for productivity development and innovation allows further innovative and more agile funding methods aiming at productivity development

Source(s): Table by authors

Table 2.

5. Conclusions

Low productivity in the infrastructure sector causes and indicates challenges in achieving the goals of sustainable, resource efficient and digitalized built environment. This paper aimed to shed light to the potential development areas by examining the question "How to enable productivity improvement in the infrastructure sector in Finland?" As a result, the iProDe-CMMI-model was constructed through utilizing research literature and interview data and validated and refined through an expert panel. Taken together, the results indicate that the constructed iProDe-CMMI-model has potential in leveraging productivity development in the Finnish infrastructure sector. The study contributes to the understanding of infrastructure system productivity and its continuous improvement capabilities. In addition, though the iProDe-CMMI appears promising in the light of the expert panel, testing and demonstration of the constructed iProDe-CMMI-model will determine its genuine applicability and effectiveness.

The findings of this study have several important implications for future practice, such as designing sector policies and productivity strategies. The constructed model provides a tool for assessing and supporting the development of the infrastructure sector as a barometer. Infrastructure owner or client organizations can utilize the model in assessing their productivity development maturity and improving their activities in aiming for infrastructure lifecycle value creation. The focal enablers also possess substantial potential for any organization to support and improve activities. The model has a potential in bringing new understanding in different solutions' effectiveness, implementation efficiency and clarity of the scope. For example, utilization of building information modeling (BIM), alliancing model, information technology (IT) solutions and collaboration networks can benefit from a more holistic examination and identification of potential bottlenecks of effective implementation.

The study has potential limitations. First, as a qualitative study, the results are dependent on researchers' interpretation. Second, the model's indicator attributes and maturity criteria are based on interview data. They are therefore subject to subjective perspectives and biases. However, they are confirmed through the expressions of multiple interviewees and their validity is assessed by an expert panel. Also, the KPAs are based on literature and they narrow down the possible indicator attributes. In any case, the indicator attributes and maturity criteria are based on and limited by, the understanding of the interviewees. Third, the study is conducted in the context of Finland. Thus, studying contexts with different cultural and governmental systems would likely find some differences. Yet, the iProDe-CMMI is likely helpful in considering infrastructure sector in any context.

Further research is needed to estimate the refinement needs, implementation methods and effectiveness of the introduced iProDe-CMMI-model. Further experimental investigations are needed on organizing the collaboration in fostering the development of these value and system-based maturities.

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Appendix: Interview questions

Roadmap to productivity leap of the infrastructure sector

Vision, politics and administration

1. What is the current state of digitalization in the Finnish infrastructure sector?
2. What are the most important development needs?

Processes and procedures

3. What procedures support/prevent efficient operations and the development of digitalization?
4. What are the most important development needs?

Technology

5. What are the bottlenecks in the utilization of technology?
6. What possibilities do future technologies offer for increasing efficiency?

Collaboration

7. What development needs can be recognized in the collaboration between different parties in the infrastructure lifecycle?
8. What are the key procedures for improving collaboration?

Ability

9. What ability needs and requirements do different parties have?
10. How can they best be answered?

Action plan

11. What are the most important steps to help the progress of digitalization and efficiency in the infrastructure sector?
12. What are, in your opinion, the most important needs future development should concentrate on?

Corresponding author
Kaisu Laitinen can be contacted at: kaisu.laitinen@tuni.fi