A novel BIM strategic plan development method for the water industry of Iran

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Abstract

Cost overrun and time delays in water industry construction projects persuade the authorities to improve the project management approach by adopting building information modeling (BIM). However, BIM is new in the water industry and, with the many aspects and extensive details involved, its successful implementation requires an effective strategic plan. To address this need, in this project a customized BIM strategic plan development method is proposed and followed for the water industry projects in Iran. As a result, two 5-year implementation phases are proposed and specifications of the required infrastructures are outlined. The first phase targets the implementation of BIM maturity level one in pilot projects and BIM maturity level two becomes mandatory at the end of phase two. To the best of the authors' knowledge, for the first time, a systematic method for the BIM strategic plan development in an industry, with multiple organizations involved, is proposed in this research. The two types of BIM committees introduced and utilized in this research can inspire other BIM strategic plan development efforts for large industries, e.g. transportation industry, the electric power industry, and the oil and gas industry, with multiple organizations in charge and different types of construction projects implemented.

Keywords: Problems of water industry; Strategic plan; Building information modeling(BIM); Readiness assessment; BIM implementation goals; BIM implementation roadmap: Iran.

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1. Introduction

Considering the arid and semi-arid climate of the vast geographical areas of Iran, water provision is nationally and strategically essential. It has always been one of the most important sociopolitical challenges in the country [1]. The growing population, increased water consumption, and water pollution from sewage systems [2-4] are expected to deteriorate the existing condition over time. The current situation necessitates the implementation of a wide range of water industry projects. Dam, water and wastewater treatment facilities, and water distribution infrastructures are among the prevalent projects performed to overcome the abovementioned challenges [5].

Water industry projects in Iran are associated with various financial, contractual, and technical issues. The financial problems include the poor government budget [6-8], high inflation [6,9], delay in payment to the contractors [6], and poor financial condition of contractors [6,9]. Contractual challenges include poor contract management [6,9], cumbersome bureaucracy in the bidding method [6], inaccurately prepared proposals by contractors [7], a shorter contract duration than the required time, the legal argument between different parts [6], and insufficient contractor skills and experience [10]. Technical problems include delays in preparing and delivering drawings, reworks in the design phase [10], partial studies before design, lack of experience in the design team, poor project scheduling, design delays [6], poor job-site management [7], insufficient attention to resource allocation [6], construction rework [6],

53 improper communication and coordination between project stakeholders [9], lack of procurement
54 procedures, and poor subcontractor management [6].
55 As a result of the existing issues, the country faces nearly 6000 half-finished projects in the water
56 industry requiring more than $25 billion to complete [11]. Given the limited government budget, these
57 projects can take decades to complete. Meanwhile, the management and planning organization (MPO),
58 which is in charge of the government's budget distribution and control, decided to adopt building
59 information modeling (BIM) technology in water industry projects. The MPO's management team
60 believed that the use of BIM capabilities can resolve many technical, financial, and contractual issues
61 that the water industry projects are struggling with.
62 ISO [12] defines BIM as the "use of a shared digital representation of a built asset to facilitate design,
63 construction, and operation processes to form a reliable basis for decisions". In recent years, BIM has
64 been introduced to the water industry. However, its growth has been slow compared to other
65 infrastructure projects [13,14]. In addition, many projects that adopted BIM technology failed to deliver
66 what they were aimed for [15]. The successful implementation of this new technology requires a
67 carefully developed BIM adoption plan tailored to the specific conditions of the water industry. For
68 example, preparations were made before the implementation of BIM in the water industry of the United
69 Kingdom and New Zealand. BIM4Water group was formed in the UK in 2013 to make policies, develop a
70 BIM strategic plan, and prepare required guidelines and instructions for BIM implementation in the
71 water industry [16,17]. This group developed a five-year roadmap for years from 2022 to 2026 with the
72 goals of gaining government support, promoting the library of BIM objects, and implementing a
73 marketing plan [18]. In New Zealand, Watercare Services Ltd, owned by the Auckland Council, was in
74 charge of BIM development as a part of the strategic transformation program since 2018 [19].
75 Watercare Services Ltd set an ambitious 40:20:20 target in its prepared strategic plan to reduce carbon
76 emissions by %40, reduce the cost by %20, and annually reduce work injuries by %20 until 2024.

As a result, BIM strategic plan development was the first move of the "Management and Planning Organization of Tehran" (MPOT) before adopting BIM in the water industry projects of Iran. A research team from the Sharif University of Technology was formed in June 2020 to develop the BIM strategic plan. However, the strategic plan development methods reported in the literature focus on BIM implementation in a single organization, and the current literature lacks a structured method for developing a BIM strategic plan in an industry, e.g., the water industry, with multiple organizations in charge of different industry sectors. Here, the research team was, first, set to propose a customized BIM implementation strategic plan method for the water industry in Iran. Then, the proposed method was piloted in the water industry of Tehran province. Following, the steps taken to propose and develop the BIM strategic plan are outlined.

2. Methodology

The research team performed an extensive literature review and thorough field study for recognizing the specific condition of the water industry in Iran and propose a tailored BIM strategic plan development method. Later on, this six-stage method was utilized in the BIM strategic plan development of the water industry of Tehran province. First, the BIM planning committees were formed. The "Regional Water Company of Tehran" (RWCT) and the "Water and Sewage Department of Tehran" (WSDT) were identified as the main executive organizations, and the "Management and Planning Organization of Tehran" (MPOT) was identified as the controlling organization in the province. Two-level BIM planning committees, including cross-organizational and organizational levels, were formed at this stage to properly capture and integrate the existing concerns of all contributing organizations. In the second stage, the identified organizations in the water industry of Tehran province were thoroughly recognized. After that, in the third stage, a customized readiness assessment method was developed and performed for evaluating the readiness level of the participating organizations. In

the fourth stage, the organizations' goals were identified and related performance indicators were defined. High-priority BIM applications were selected in the fifth stage. Finally, in the sixth stage, separate and integrated BIM strategic plan documents were prepared for the RWCT, WSDT, and MPOT. Fig. 1 presents an overview of the proposed BIM strategic plan development method. Following, the different stages taken for the implementation of the proposed method in the water industry of Tehran province are explained.

3. Forming the BIM committees

Forming a BIM planning committee, consisting of key members from different parts of the organization, is the first stage of the BIM strategic plan development [20]. The use of a BIM committee to facilitate, coordinate and direct BIM strategic plan development is frequently reported in different countries. Several examples of these committees include the BIM committee in the UK [21], the BIM delivery team in the US Corps of Engineers [22], the steering committee in Singapore [23], BIM acceleration committee in New Zealand [24,25] and BIM strategic committee in Brazil [26].

Since multiple organizations were in charge of water industry projects, a two-level BIM committee structure was formed during the BIM strategic plan development process. At the top level, a cross-organizational BIM committee that included representatives from three main contributing organizations, including RWCT, WSDT, and MPOT, was formed. Each contributing organization had one representative in the committee appointed by the organization's chief executive officer (CEO). The BIM development team held several training sessions for the committee members and facilitated the committee's formation. The committee was established to assure consistency of the developed plan for different organizations and facilitate the provision of the statutory requirement for the BIM implementation. The committee members' mission was to facilitate the communication of the BIM strategic plan development team with their organizations.

At the second level, three intra-organizational committees were formed for each contributing organization. The organizations' representatives in the cross-organizational committee facilitated the formation of the intra-organizational committees and worked as the intra-organizational committees' coordinators. The intra-organizational committees comprised key organization members from different departments and received formal appointments from the organization's CEO. Here, BIM strategic plan development team held separate BIM training sessions for each intra-organizational committee. During the strategic plan development process, the intra-organizational committee members facilitated the organizational recognition process, participated in the organizational goal identification sessions, and worked as BIM advocates in their departments.

4. Organizational recognition

The contributing organizations in the project were large organizations consisting of various departments, thousands of employees, and multiple buildings and facilities. An efficiently planned recognition stage was quite vital for the successful implementation of this stage. As a result, a comprehensive literature review was performed to identify organizational parameters affecting BIM implementation, and the research team collected information for these organizational parameters. In total, 16 different organizational parameters were identified. Past research [27-29] categorizes these parameters into four main categories, linked to four different organization's aspects, including 1) management, 2) process, 3) technology, and 4) staff. The parameters within each category were divided into subcategories to effectively describe different angles of the organizations' aspects, and questions were designed to evaluate each parameter. Multiple approaches, including questionnaire surveys, interviews, and review and analysis of the documents, were planned and followed for collecting answers to different questions. Table 1 presents the identified parameters, categorization structure, and data collection approach adopted in the recognition stage.

Here, no or minimal BIM applications were identified in the organizations' projects. All organizations were categorized as BIM maturity level of zero [30].

5. Organizational readiness assessment

The organizations' readiness was evaluated based on responses received for the designed questions. Since each organizational aspect was described by multiple parameters and each parameter was evaluated based on the designed questions, the organization's readiness in each aspect and for each parameter was measured by aggregating the corresponding questions. However, responses to the questions were different in nature and were evaluated in different measures. The research team normalized the achieved values between 0% and 100% to facilitate the aggregation processes based on the following guidelines.

- For the five-level Likert-based parameters, the value of 1 represented 0%, and the value of 5 represented 100%. The in-between values were proportionally calculated.
- In the yes/ no or true/ false responses, yes or true represented 100% and no or false represented 0%.
- For the percentage-based values, the percentage obtained was directly considered.

The organizations' readiness in different aspects and parameters was calculated as a simple average of the normalized values. **Error! Reference source not found.** represents the evaluated readiness in different aspects of the contributing organizations. The achieved results set baselines for monitoring each organization's readiness improvement over time.

6. Method for identifying the improvement tasks

One of the main purposes of the readiness assessment stage was to identify readiness improvement tasks that enable each organization to properly implement its desired BIM applications. The implementation complexity of different BIM applications, however, can be quite different,

considering the extent of the project team's involvement in the application. A high readiness is required for implementing complex applications while implementing simple BIM applications relatively requires a low readiness. Baldwin [31] illustrates BIM application complexity in a form of the BIM pyramid, divided into three levels. The first level of BIM applications only utilizes the 3-dimensional (3D) feature of BIM models. In these applications, normally 3D representations of construction projects enhance project stakeholders' comprehension of the project outcomes. BIM applications at this level are mainly implemented during the initial stages of the project development, including project definition, feasibility study, and investment attraction. Project owners are the main users of the BIM applications at this level.

In the second-level BIM applications, in addition to the 3D geometry of the BIM model, the information content embedded in the BIM models is utilized. BIM-based project energy analysis and material quantity take-off are examples of these applications. BIM applications at this level are mainly performed during the design and planning phases. In the third level, BIM applications merge with the project management processes. BIM applications for improving project progress control and project quality control are samples of this level. BIM applications at this level are performed during the construction and operation phases. **Error! Reference source not found.** represents the three levels of BIM application complexity in the form of the BIM pyramid introduced by Baldwin [31].

Here, a three-level evaluation approach was considered for the required readiness; 0% value indicated no readiness required, 50% value indicated partial readiness required, and 100% value indicated complete readiness required. The research team consulted with the organizational BIM committees to determine the required readiness values in every organizational parameter at each level of BIM application complexity. The improvement tasks were recommended where the evaluated readiness for an organizational parameter was less than the required value. **Error!**

Reference source not found. lists the values achieved for each organizational parameter in the contributing organizations and the required values for three levels of the BIM application complexity. This table was used for identifying required tasks based on the adopted level of complexity.

7. Setting organizational goals

Organizational goals were set in several steps. First, a long list of BIM implementation goals was formed based on an extensive literature review. Here, 28 goals were identified and grouped into organizational goals in four main phases: pre-construction, construction, post-construction, and multiple phases. Table 3 represents the identified BIM implementation goals.

In the second step, the prepared long list was presented and explained to the management team by the research team and each management team member identified its desired goal from the list. In the third step, the research team prioritized the organizational goals based on the management team's input for each contributing organization.

Performance indicators (PIs) were required to monitor the effects of BIM implementation in each organization. Therefore, the research team contacted different parts of each organization to collect their existing PIs and propose a set of PIs for measuring the effects of BIM implementation. In the fourth step, the intra-organizational committee members participated in finalizing the adopted goals and their associated PIs. Table 4 presents the high-priority goals and their associated PIs.

8. Selecting high-priority BIM applications

The research team determined the associated BIM applications to different organizations' goals, presented these applications to the organizational BIM committee members and discussed their implementation impacts. The organizational BIM committees, then, determined the priority of BIM application implementation in their projects.

218 presents the high-priority BIM applications selected in each contributing organization.

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9. Developing the strategic plan

The BIM implementation strategic plan was divided into two 5-year phases. Since all contributing organizations were in the zero maturity level, in the first phase, implementation of BIM maturity level of 1 (Shepherd 2019) was planned in pilot water industry projects. In this phase, only the implementation of BIM applications with complexity levels of 1 and 2 was recommended. This approach saves time for the organizations to enhance their capabilities to adopt complex BIM applications with complexity levels of 3. The developed plans were relatively similar for the RWCT and WSDT organizations. Both of these organizations were in charge of water resource projects in their specified sector, both were standing in relatively similar readiness levels, and similar complexity levels were set for their adopted BIM applications. At the top level, the operational plan of the first phase was divided into three main categories, including 1) personnel readiness enhancement, 2) provision of management, process, software, and hardware infrastructures, and 3) pilot BIM-based project implementation. The required improvement tasks were identified based on measures set in Table 2. The first phase of the developed plan was divided into two periods of three years, with one year of overlap. The focus of the organizations in the first period of the first phase was on the preparation of the required BIM infrastructures, while BIM is implemented in a limited number of pilot projects. In the second period of this phase, the majority of required infrastructures are delivered and the number of pilot BIM-based projects increases.

The developed operational plan for MPOT was, nevertheless, different from the two other contributing organizations. MPOT was a supporting organization providing budget, legal platforms, and processes required in the different water industry projects. The research team assigned the provision of shared software and hardware infrastructures to the MPOT. These infrastructures include domestic BIM collaboration format (BCF) software, internet-based BIM visualization software, the library of parametric BIM-based objects, and their associated hardware. These operational improvement tasks were planned for the first three years of the first phase. Here,

actively embracing the cross-organizational BIM committee can play a key role in properly conveying each contributing organization's needs during the development of the shared infrastructure. Fig. 4 outlines the operational improvement tasks planned for the contributing organizations in the first phase of the strategic plan.

In the second phase of the BIM implementation strategy, the implementation of BIM applications with all three levels of complexity in the BIM maturity level of 2 was planned. The operational plan of BIM implementation in the second phase was quite dependent on the BIM implementation outcome in the first phase. Therefore, the operational plan preparation for the second phase was postponed to the third and fourth years of the BIM implementation in the first phase to receive proper feedback. Fig. 5 represents an overview of the BIM implementation roadmap in the two adopted phases.

Separated BIM strategic plan documents were prepared for each contributing organization. Prepared documents were, first, presented to the intra-organizational and cross-organizational committees, and their final approval was received. Then, the plan was presented to each organization's members, and their associated consulting engineers and contractors. Water industry authorities in other provinces were also invited and participated in these sessions.

10. Discussion

A customized BIM implementation strategic plan development method was proposed and followed in this research as a result of an extensive literature review and thorough recognition of the water industry. The validity and applicability of the proposed method were tested in the water industry of Tehran province. A two-level BIM committee structure was formed and a customized readiness assessment was performed for the water industry of the province. Two 5-year BIM implementation phases were considered in the BIM strategic plan and the required operational readiness improvement tasks were identified and scheduled for the first five years. BIM capabilities adopted

for each participating organization and the prepared readiness plan were assessed by each organization's experts and adjustments were made based on their input. Here, the involvement of the key industry experts in the intra-organizational and cross-organizational levels of the strategic plan development process improved the face validity of the developed strategic plan. The dynamism and complexity involved in different parts of the industry, however, could deviate the implementation results from the prepared plan. Therefore, annual strategic plan evaluation points were set to monitor and control BIM implementation efforts in the contributing organizations to adjust the industry moves based on the most recent results.

11. Conclusions

Annually, many construction projects implemented to improve the efficiency of water resource consumption in Iran. Water industry projects attract a high amount of the country's public construction budget. However, many of these projects suffer from time delays and cost overruns. The use of BIM capabilities was recommended to the water industry authorities for improving the performance of these projects. BIM implementation, however, bears many aspects and technical details. Proper implementation of this technology in the water industry requires an adequately prepared BIM strategic plan.

The BIM strategic plan development method proposed in this research was successfully piloted in the water industry of Tehran province.. The approach followed in this research can inspire other organizations and researchers for developing BIM strategic plans for water industry projects in other countries. The two-level BIM-committee formation approach introduced in this research can be followed by other industries such as the transportation industry, electric power industry, oil and gas industry, and mining industry, that require the implementation of different types of construction projects to fulfill their expected missions.

The proposed method in the research was only piloted in one case, i.e., Tehran province. Further implementation cases are required to evaluate the capabilities of the method. In future research, it is recommended that the achieved results of the BIM strategic plan implementation are closely observed, and possible impacts of BIM implementation on existing issues are analyzed. As a next step to the BIM strategic plan development, BIM execution plan (BEP) methods need to be prepared for the BIM implementation in different water industry projects. BIM implementation challenges and concerns in various types of water industry projects, e.g., dams, water treatment plants, water distribution networks, sewage collection networks, and sewage treatment, need to be researched.

Statements & Declarations

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Competing Interests

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Author Contributions

Amin Alvanchi contributed to the study conception, design of methodology, research team supervision, data collection, data analysis, and paper preparation. Mohammad Amin Jafari contributed to the literature review, data collection, data analysis, and paper preparation. Nasim Didehvar contributed to the literature review, data analysis, and paper preparation. All authors read and approved the final manuscript.

Availability of Data and Material

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical Approval

The research is performed under contract number 109750 between the research team and the Management and Planning Organization of Tehran Province. The Management and Planning Organization of Tehran Province has approved the outcome of the research. The authors have obtained the right of research result publication according to clause no. 30 of the contract condition.

Consent to Participate

All participants in the research were formally bound to/ hired by the Management and Planning Organization of Tehran Province and participated in the research as a part of their organizational duties.

Consent for Publication

The authors have obtained the right of research result publication according to clause no. 30 of the condition part of contract number 109750. Hereby, the authors declare their consent for the publication of the manuscript in this journal.

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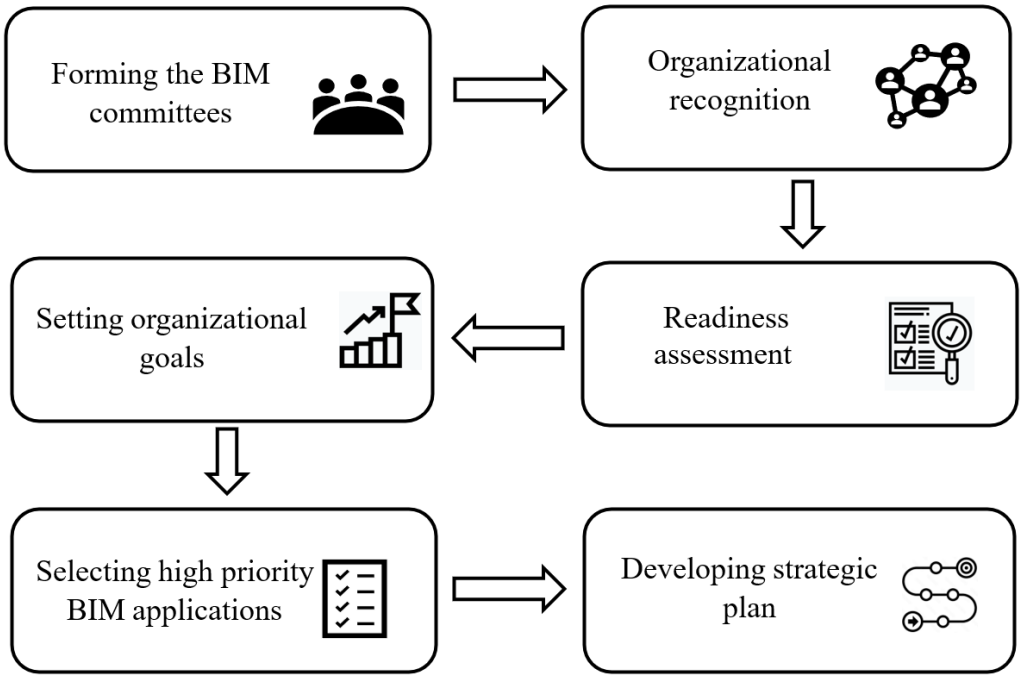


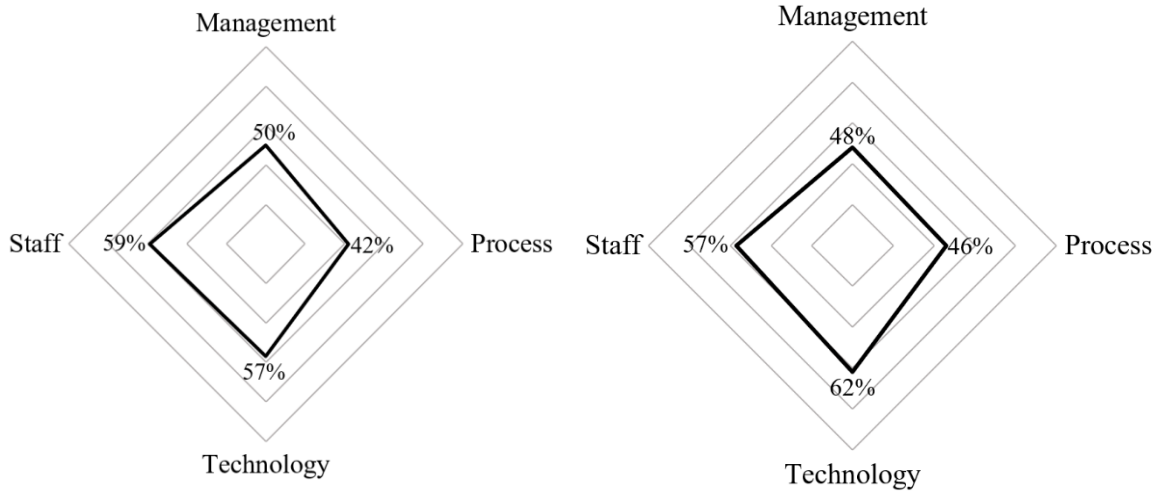
Fig. 1 *An overview of the proposed BIM strategic plan development method*

520 ***Table 1*** *Identified parameters, categorization structure, and data collection approach*

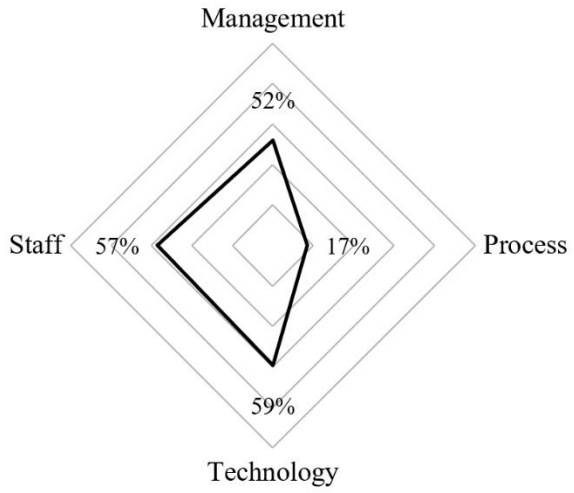
Category	Subcategory	Parameter	Question	Data collection approach
Management	Management strategy	BIM in the organization's goals, vision, and mission	Does the organization have vision and mission documents?	Review of the documents
			Is the application of BIM considered in the vision and mission documents?	
			Are the organizational goals set?	
			Is the organization targeted to apply BIM?	
			Is the movement of the organization determined to achieve the goals?	Questionnaire
		Organization's ability to apply new project management methods	Does the management apply new methods for the development of the organization?	Questionnaire
		Willingness and support of organization's managers to use BIM	Is there a certain plan to use BIM in the organization?	Review of the documents
			How do you evaluate the organization's management support for BIM implementation?	Questionnaire
		Incentive policies to encourage or require staff to use BIM	How do you evaluate incentive policies to encourage or require staff to use BIM?	
	External pressure	Pressure from the government to implement BIM	How do you evaluate the government pressure for implementing BIM?	
	BIM understanding	Management recognition of BIM	How do you evaluate the level of top managers' knowledge about BIM?	Interview
Process	Processes in the organization	BIM in contracts and project delivery methods	Have you ever required consultants/contractors to use BIM in contracts?	Interview
			Are there BIM contract attachments in the organization?	Review of the documents
			Do you have specific instructions for using BIM in your project contracts?	
		Information exchange method and workflow efficiency	Do you have specific instructions about exchanging project information among stakeholders?	Review of the documents
			Are there instructions for naming technical documents in the organization?	
			Do you have specific BIM-based instructions about exchanging your project information among stakeholders?	
		Interaction and group work processes	Do you have a certain plan for managing your projects?	Review of the documents
			Is there a clear process for integrating design disciplines in the organization?	

Category	Subcategory	Parameter	Question	Data collection approach
			Is the work assignment process and collaboration between different parts of the organization adequately defined?	
			Is there a pre-defined process for information exchange and delivering as-built documents to the facility management team?	
			Do you have organizational roles associated with BIM in the organization?	
			Is there an asset management process in the organization?	
Technology	Software infrastructure	Software infrastructure requirements	Do you use updated software to do your work?	Questionnaire
			Do existing IT policies encourage the use of the latest software technologies?	
	Hardware	Hardware infrastructure requirements	Do you consider the specifications of your computer to fit your tasks?	Questionnaire
			Does your organization's intranet network effectively work?	
			Do you have access to a fast and reliable internet connection in the organization?	
	Technical support	Technical support requirements	How do you evaluate the quality of software update services?	Questionnaire
			How do you evaluate the quality of support services in case of software problems?	
			How do you evaluate the quality of hardware upgrade services?	
			How do you evaluate the quality of support services in case of hardware problems?	
			How do you evaluate the quality of service updates of the organization's computer network capabilities?	
			How do you evaluate the quality of support services in case of problems in the organization's computer network?	
Staff	Skill	Staff's BIM knowledge	How do you evaluate the expertise of the staff assigned to different positions in the organization following their duties?	Questionnaire
			What technical and general software packages are you familiar with?	
			What BIM-based software packages are you familiar with?	
		Staff willingness to learn and accept new technology and methods	How do you evaluate staff's willingness to learn new technologies and methods of project management?	Questionnaire
			How do you evaluate staff's willingness to learn new software to do their assigned task?	
			Are the staff ready to receive new training (especially in software)?	Interview
		Staff's pace in the acceptance of new technology	How do you evaluate the pace of staff in accepting changes and implementing new technology in the organization?	Questionnaire
	Work environment	Level of interaction and cooperation	How do you evaluate the level of cooperation among the organization's staff?	Questionnaire

Category	Subcategory	Parameter	Question	Data collection approach
		among staff		



a. *RWCT* ***b.*** *WSDT*



c. *MPOT*

Fig. 2 *Results of readiness assessments for the contributing organizations*

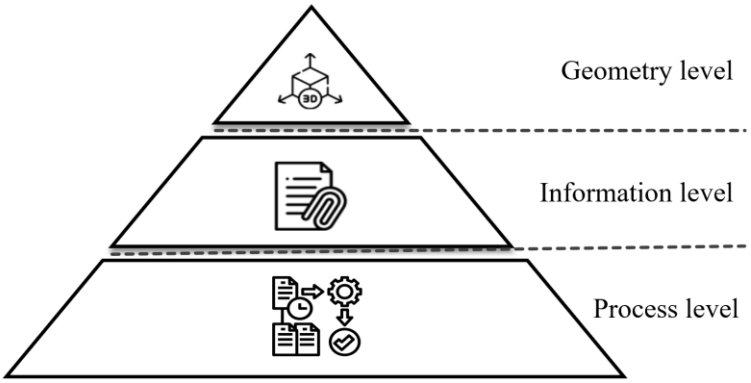


Fig. 3 *The BIM application complexity levels or BIM pyramid [31]*

560 ***Table 2*** *The required and achieved organizational parameter values (Percentage)*

Category	Question	Required Value			Achieved Value		
		Level 1	Level 2	Level 3	RWCT	WSDT	MPOT
Management	Does the organization have vision and mission documents?	100	100	100	100	100	100
	Is the application of BIM considered in the vision and mission documents?	100	100	100	0	0	0
	Are organizational goals set?	100	100	100	100	100	100
	Is the movement of the organization determined to achieve the goals?	100	100	100	68	61	73
	Is the organization targeted to apply BIM?	100	100	100	0	0	0
	Do the management team apply new methods for the development of the organization?	50	100	100	66	63	73
	Is there a certain plan to use BIM in the organization?	100	100	100	0	0	0
	How do you evaluate the organization's management support for BIM implementation?	50	100	100	76	62	76
	How do you evaluate incentive policies to encourage or require staff to use BIM?	50	50	50	56	60	63
	How do you evaluate the government pressure for implementing BIM?	50	50	50	52	55	62
	How do you evaluate the level of the top management’s knowledge about BIM?	50	50	100	30	30	30
Process	Have you ever required consultants/contractors to use BIM in contracts?	50	100	100	100	0	0
	Are there BIM contract attachments in the organization?	50	100	100	0	0	0
	Do you have specific instructions for using BIM in your project contracts?	50	100	100	0	0	0
	Do you have specific instructions about exchanging project information among stakeholders?	0	100	100	100	100	100
	Are there instructions for naming technical documents in the organization?	50	100	100	100	100	0
	Do you have specific BIM-based instructions about exchanging your project information among stakeholders?	50	100	100	0	0	0
	Do you have a certain plan for managing your projects?	50	100	100	0	0	0
	Is there a clear process for integrating design disciplines in the organization?	0	100	100	0	50	0
	Is the work assignment process and collaboration between different parts of the organization adequately defined?	0	50	100	100	100	100
	Is there a pre-defined process for information exchange and delivering as-built documents to the facility management team?	0	0	100	100	100	0
	Do you have organizational roles associated with BIM in the organization?	50	100	100	0	0	0
	Is there an asset z process in the organization?	0	50	100	0	100	0

Category	Question	Required Value			Achieved Value		
		Level 1	Level 2	Level 3	RWCT	WSDT	MPOT
Technology	Do you use updated software to do your work?	50	100	100	70	70	66
	Do existing IT policies encourage the use of the latest software technologies?	50	100	100	58	66	66
	Do you consider the specifications of your computer to fit your tasks?	50	100	100	62	63	60
	Does your organization's intranet network effectively work?	50	100	100	70	68	61
	Do you have access to a fast and reliable internet connection in the organization?	0	100	100	48	50	63
	How do you evaluate the quality of software update services?	50	100	100	52	60	58
	How do you evaluate the quality of support services in case of software problems?	100	100	100	58	64	56
	How do you evaluate the quality of hardware upgrade services?	50	100	100	44	54	51
	How do you evaluate the quality of support services in case of hardware problems?	100	100	100	46	60	53
	How do you evaluate the quality of service updates of the organization's computer network capabilities?	0	50	50	58	59	56
	How do you evaluate the quality of support services in case of problems in the organization's computer network?	0	50	50	56	65	58
Staff	How do you evaluate the expertise of the staff assigned to different positions in the organization following their duties?	100	100	100	56	51	54
	What technical and general software packages are you familiar with?	50	100	100	64	54	71
	What BIM-based software packages are you familiar with?	100	100	100	28	19	21
	How do you evaluate staff's willingness to learn new technologies and methods of project management?	100	100	100	74	57	65
	How do you evaluate staff's willingness to learn new software to do their assigned task?	100	100	100	54	79	83
	Are the staff ready to receive new training (especially in software)?	50	50	50	80	80	40
	How do you evaluate the pace of staff in accepting changes and implementing new technology in the organization?	50	50	100	54	57	57
	How do you evaluate the level of cooperation among the organization's staff?	50	50	100	62	61	64

561 ***Table 3*** *BIM implementation goals in different phases of the construction project's life-cycle*

Pre-construction phase
Using preliminary BIM models in the feasibility study and visualization [15,32,33,34]
Attracting investors by providing preliminary project models and convincing them [35,36]
Reducing interference, claims, cost overruns, and delays by the earlier collaboration of multiple design disciplines [20,37,33,15]
Ensuring that the plans fully comply with the demands, expectations, and requirements of the organization [38]
Improving construction quality and performance by evaluating different design alternatives in the early stages of the project [33,34,15]
Better interaction of the owner team with other stakeholders in the selection of suggested designs and better decisions of the owner in the early stages [37]
Value engineering implementation in the design phase [39]
Improving project sustainability and analyzing energy performance [40,33,15]
Availability of detailed quantity take-offs and project estimates at each stage of the design phase [33,41]
Construction phase
Better planning of the workshop equipping [42]
Reducing rework and change orders [32]
Efficient management of changes [40]
Employing design, monitoring, and consulting teams non-established at the project site using an interactive space [43]
Schedule projects accurately by using 4D models [44]
Increasing the safety of projects [34,15]
Using 5D models for accurate project cost estimation and budgeting [44]
Post-construction phase
BIM application in the asset management phase in the organization [15]
Having a reliable as-built model during operation [45]
Preservation of life-cycle information in models and its application in operation, maintenance, and facility management [41]
Increasing the resilience of organizations during force majeure due to better information management [35]
Accurate project facility management phase using 6D models [41,33]
Multiple phases
Improving communication and cooperation between different project stakeholders by reducing paper correspondence [40,32,34,46]
Creating an integrated information network between stakeholders and better and faster information sharing [41]
Increasing project productivity by creating an interactive space between project stakeholders [40,32,34,46]
Improving the information documentation system by creating a suitable platform for storing and retrieving all project information and using it in future projects [15,35]
Better cost control at all stages of the project life-cycle and increasing project profits and implementation speed [41]
Better risk management [47,35]
Reducing contractual risks and the costs allocated to them [48]

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565 ***Table 4*** *High-priority goals and associated performance indicators in the contributing organizations*

Goals	Performance indicators	RWCT	WSDT	MPOT
Reducing the implementation cost	Project cost performance index	✓	✓	✓
	Percentage of projects following the budget in the organization	✓	✓	✓
Reducing the implementation time	Project schedule performance index	✓	✓	✓
	Percentage of projects on schedule in the organization	✓	✓	✓
	Percentage of stopped projects in the organization	✓	✓	✓
Reducing the safety accidents in the project implementation	Annual average of project's incident rates	✓	✓	□
Reducing the scope change	Percentage of project amendments	✓	✓	✓
	The value ratio of the scope change in the project	□	□	✓
	The value ratio of the total scope change in the organization's projects	□	□	✓
	The value ratio of the scope change caused by the executor	□	□	✓
	The value ratio of the scope change caused by the operating organization	□	□	✓
	The value ratio of the scope change caused by consulting engineers because of design and estimation problems	□	□	✓
	The value ratio of the scope changes due to the lack of technical and executive capability of the contractor	□	□	✓
Reducing legal disputes	Annual percentage of legal claims	✓	✓	✓
Reducing maintenance costs	Per capita maintenance and repair costs	✓	✓	✓
Improving the functionality of the facility	Satisfaction level of the facility operation management team	✓	□	✓
Facilitating projects' cash inflow	Percentage of annual budget allocated to the project	□	□	✓
	Percentage of annual overall budget allocated to an organization	□	□	✓
Increasing the quality of project execution	Percentage of compliance with the regulations in projects	□	□	✓
	Percentage of expert executive staff in projects	□	□	✓
	Percentage of compliance of implemented projects with executive plans and specifications	□	□	✓

Improving projects' feasibility	Percentage of annual objectives achieved after project operation	□	□	✓
	Percentage of annual objectives achieved in the organization	□	□	✓

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567 ***Table 5*** *High-priority BIM applications in the contributing organizations*

BIM Application	BIM Application Complexity Level	RWCT	WSDT	MPOT
Using preliminary BIM models in the feasibility study and visualization	1	✓	✓	✓
Better interaction of the owner team with other stakeholders in the selection of suggested designs and better decisions of the owner in the early stages	1	✓	✓	□□
Improving construction quality and performance by evaluating different design alternatives in the early stages	1	✓	□	□
Ensuring that the plans fully comply with the demands, expectations, and requirements of the organization	1	✓	✓	✓
Attracting investors by providing preliminary project models and convincing them	1	✓	✓	✓
Value engineering implementation in the design phase	2	✓	✓	□
Reducing interference, claims, cost overruns, and delays by the earlier collaboration of multiple design disciplines	2	✓	✓	✓
Availability of detailed quantity take-offs and project estimates at each stage of the design phase	2	✓	□	□
Schedule projects accurately by using 4D models	2	✓	□	□
Using 5D models in accurate project cost estimation and budgeting	2	✓	□	□
Better planning of the workshop equipping	2	✓	□	□
Improving construction quality and performance by evaluating different design alternatives in the early stages of the project	2	□	✓	□
Improving project sustainability and analyzing energy performance	2	□	✓	□
Creating an integrated information network between stakeholders and better and faster information sharing	2	□	✓	□
Availability of detailed quantity take-offs and project estimates at each stage of the design phase	2	□	□	✓
Increase construction quality	3	✓	□	□
Improving the information documentation system by creating a suitable platform for storing and retrieving all project information and using it in future projects	3	□	□	✓

Increasing the resilience of organizations during force majeure due to better information management	3	□	□	✓
BIM application in the asset management phase in the organization	3	□	□	✓

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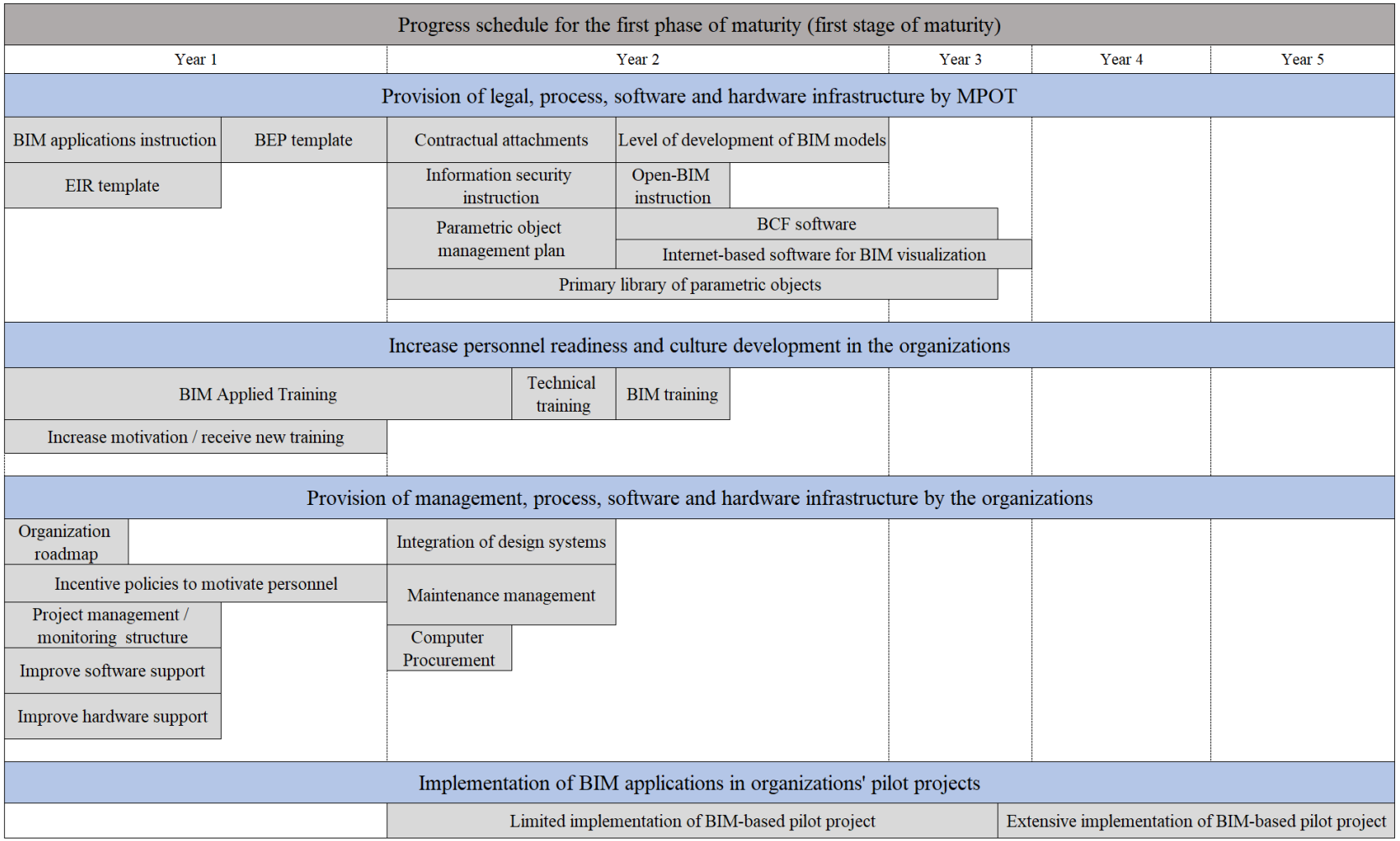

Fig. 4 *Operational plan of the first phase of BIM implementation in organizations*

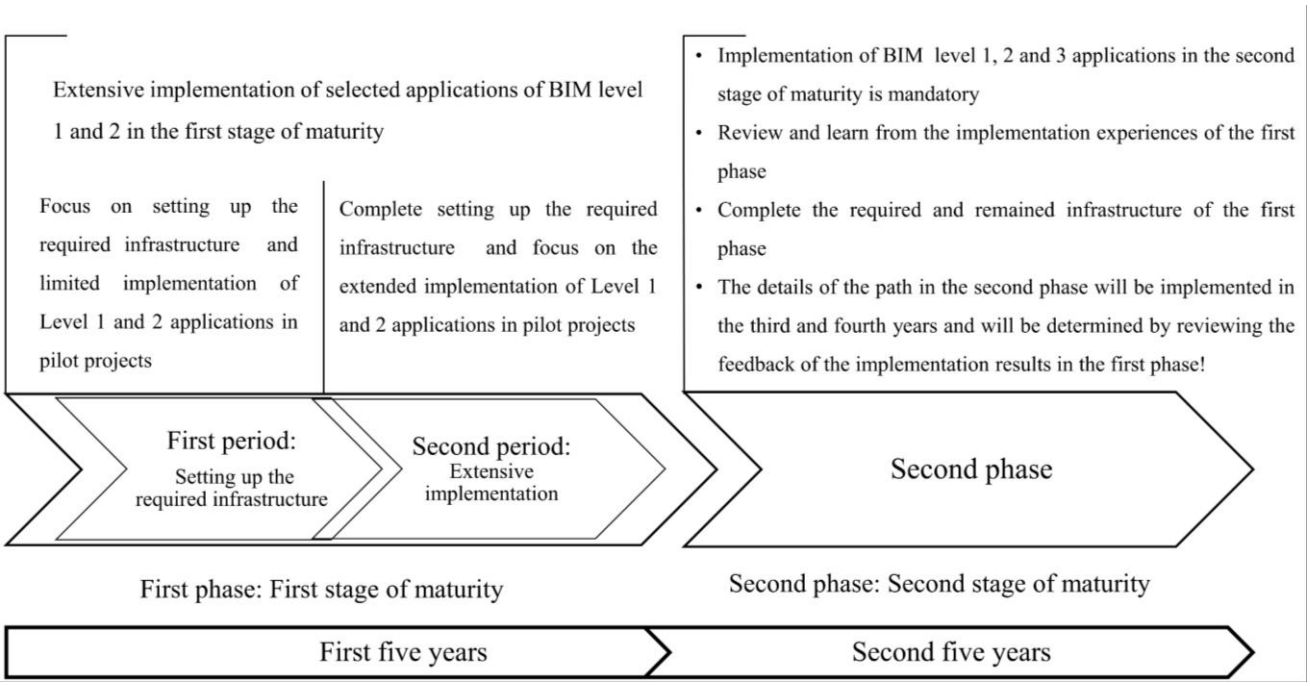

Fig. 5 *BIM implementation roadmap in two phases*