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RESEARCH PAPER

Building Information Modeling Deployment in Oil, Gas and Petrochemical Industry: An Adoption Roadmap

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ABSTRACT: The implementation of Building Information Modeling (BIM) in the Architecture, Engineering and Construction (AEC) industry is growing rapidly. The Oil, Gas and Petrochemical industry (OGPi), however, is still lagging in harnessing the BIM capabilities. Therefore, the main question of this research is: How and what actions should be adopted for deploying BIM in the OGPi? The research is divided into three parts as an action research. This study investigates the second part, namely preparation of an adoption roadmap for deploying BIM in collaboration with Integrated Project Delivery (IPD) in the OGPi. To achieve this goal, an extensive literature review including the most established roadmaps in the AEC industry and also the semi-structured interviews with the OGPi's experts are conducted. Then, an adoption roadmap is derived for OGPi via Innovation Diffusion Theory (IDT), 'Why, How, What' questions (Sink model), strategic planning and innovation roadmap as well as the iterative process in the studies and interviews. The prepared roadmap validated by triangulation through focus group meetings and oils the wheels of BIM implementation alongside with IPD in the OGPi firms to grabs BIM merits and harness its challenges. Finally, the major limitations and the required future studies are addressed.

Keywords: Adoption Roadmap, BIM, IDT, Integrated Project Delivery, OGP Industry.

1. Introduction

Oil, Gas and Petrochemical (OGP) industry has important differences with the Building (AEC) industry, such as: the high-risk atmosphere for all parties in whole lifecycle, need to high-quality material and equipment due to harsh operating environment, vast investment, long-term construction period, high complexity, high-

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level technical requirements, multidisciplinary team working through whole lifecycle, and many other aspects (Song, 2007). Nowadays, due to the complexity of civil and infrastructure projects including the AEC, Non-Building (NB) projects and Oil, Gas and Petrochemical Industry (OGPi), new construction management theories are needed to achieve higher performance and greater improvement (Le et al., 2018). In this regard, to overcome the big dilemmas of project complexities, the Integrated Project Delivery (IPD) and Building Information Modelling (BIM) have been emerged as the enhanced ideas for crossing the operational and technological perspectives of the project complexities (Singh et al., 2017; AIA, 2014).

Due to the differences with respect to other industries including AEC, OGPi has already moved towards the new theories of construction management to achieve the improved performance (Rui et al., 2017; Songhurst, 2014). For this purpose, OGPi has started implementing IPD methods to overcome the low efficiency and productivity issues since 1990 (O'Connor, 2009). According to AIA (American Institute of Architects), the most recent definition of IPD is defined as: A project delivery method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimise efficiency through all phases of design, fabrication and construction (AIA, 2014). The minimum elements of IPD approach consist of six major characteristics: 1) A multi-party contract; 2) Early involvement of key partners; 3) Collaborative decision making and control during whole project lifecycle; 4) Shared risks and rewards based on project outcomes; 5) limited liability among key partners; and 6) Developing project objectives jointly (Ghassemi, 2011; AIA, 2014). These characteristics are widely distinct from the traditional project delivery characteristics (Bosch-Sijtsema, 2019) and they are referred to as IPD1 to IPD6 in this study, respectively.

Despite the fact that the OGP industry is wider and more complex than AEC industry (Wang et al., 2016), OGPi has demonstrated its incentivises and capabilities for using the digital modelling technologies to improve the cost, time, quality and efficiency which is very similar to BIM as the novel idea (Lee et al., 2016). Furthermore, projects of the oil, gas and petrochemical industry are more structured and the key partners are familiar with the concept of integrated project delivery. Considering these issues, this research aims to investigate the adoption of BIM technology in collaboration with IPD method to achieve a modern method in the OGPi firms to overcome the low productivity and efficiency. The previous study in the first part of this research clearly showed that the BIM has not yet been implemented in the oil, gas and petrochemical industry and there is still a deep gap for its deployment in this context (Fakhimi et al., 2017). Since the projects of the oil, gas and petrochemical industry have wider and larger technical, financial and executive dimensions than the AEC industry projects, many attempts are needed to alleviate the losses and wastes and improve the productivity and efficiency. This need has been further increased in the current situation, as the global oil price has fallen and the recession caused by the lack of projects has hit the industry.

The research objective is to offer an insight and provide the valid information necessary to help the study make the right decisions about BIM adoption in OGPi firms alongside IPD. For this purpose, in the first part of this research, the data is gathered through the literature review and interviews and show that BIM can be highly beneficial for OGP industry and can empower it quicker than before. The first part consists of: 1) The shortage of appropriate research; 2) The implementation of BIM in OGPi has not yet been launched systematically; and 3) The need for an expressive strategy that can harness the challenges and offer a BIM implementation guideline for OGPi firm's projects.

The aim of this part of the research is to identify the causes that challenge the BIM adoption in OGPi firms and to derive a roadmap for an optimised and structured adoption process in the OGPi firms. In this way, it can lubricate the wheels of BIM implementation and its synergism with IPD in the OGPi firms to grabs BIM merits and harness its challenges. In the next part, what has been done in the OGP industry for BIM is stated. After that, the research method and results are presented. In the results section, the way of preparing the roadmap along with the necessary activities and actions for its implementation are presented. At the end, findings including the roadmap and conclusion are given.

2. Background

Almost a decade ago, AEC industry has introduced and implemented the Building Information Modelling (BIM) (Azhar et al., 2012). There are too many different definitions for BIM, but as a commonly appreciated definition, BIM is the digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life-cycle, defined as existing from earliest conception to demolition (NIBS, 2007).

A review of the way BIM has been launched in different countries and organisations has made it clear that they have prepared a roadmap for BIM adoption before taking any other action (Khosrowshahi, 2012; Hafizah et al., 2015; Silva et al., 2016). According to Bob Galvin, former CEO of Motorola, an all-encompassing view of the future about a specific field using collective knowledge and considering of the brightest drivers of change in that field is called the 'roadmap' (Cetindamar et al., 2013). The roadmapping approach has many cited benefits. However, the communication across functional and organisational boundaries is the most frequently cited benefit (Phaal, 2015).

Performing a relatively comprehensive review of the use of BIM has revealed the application of this technology in the OGP industry. It has shown that, with the exception of a limited number of cases that have implemented BIM in some part of life cycle (Table 1), no cases have been reported on the use of BIM in whole lifecycle of the oil, gas and petrochemical industry firms and their projects (Cheng et al., 2016). In addition, in another research on 28 BIM instructions from around the world, 83 academic papers and 101 case studies concerning the digital modelling in the OGPi showed that the overlapped applications of BIM in the AEC industry and digital modelling in the OGPi are overwhelming. The research described 36 BIM applications that were very similar to digital modelling applications and could be used in the OGPi (Lee et al., 2016). In fact, it highlighted the lack of research on the implementation of BIM in OGPi and its importance.

On the other hand, a study was previously conducted as the first part of this research to investigate the influence of BIM on the oil, gas and petrochemical industry. The way of implementing BIM and how to overcome the challenges were the main concern of the OGPI experts. The strategic level persons generally focused on the challenges that effected their organization characteristics like standard BIM contract, needed business model, main requirements of the BIM implementation (cost, time, tools, etc.) and financial benefits. At the tactical level any changes that affected the execution of the project like data exchange methods, interoperability, needed training, work processes and workflows, staff roles and responsibilities, information flow management and parties' roles and responsibilities, were placed in the center of their concern. The operational level persons were concerned over new methods and standards, applicability of specialized software, required training, integration of information, and redefining staff roles and responsibilities. In the first part, it was shown that BIM research should be in line with the OGP industry trend and needs to providing an adoption roadmap was recommended in this regards. It was concluded that an appropriate roadmap accelerates BIM implementation alongside IPD in the OGPi firms (Fakhimi et al., 2017). Thus, given the capabilities and flexibility with which a roadmap can be used as an efficient and powerful tool for deploying strategic plans, this research conducted the BIM roadmap and accomplished related actions for the OGPi firms. To this end, this study was inspired by the long-term strategic planning of complex projects (Shadid, 2017) in AEC industry in the countries such as England (Khosrowshahi, 2012), Hong Kong (Construction Industry Council, 2014), Portugal (Silva et al., 2016), Canada (Building SMART Canada, 2014), Australia (Hafizah et al., 2015) and Singapore (Teo et al., 2016) for adopting and deploying BIM in the AEC industry where the roadmap played a pivotal role in providing the right path based on the identification of the existing situation and the related implementation challenges.

3. Research Design and Methods

3.1. Research Design

The present research is planned as an action research that uses the reflective practice method. It is divided into three parts (Figure 1). At the first part, the capabilities of BIM in OGPi, the related challenges and the most important prerequisite for deploying BIM in OGPi are addressed via the literature review and interviewing with the experts of Iranian OGPi firms. The present study (the second part of the research) focuses on deriving BIM adoption roadmap alongside IPD for the OGPi firms through the recommendations of the first part and an iterative process based on the comments from the specialists (Figure 1). The research is designed in the context of Iranian OGPi firms so as to make it possible to evaluate the results using the views of experts. Considering the scope of this study, the phases of implementing and evaluating the actual process are performed in the third part of the research. Hence, the evaluation of the results in the form of roadmap implementation in a realistic case is performed in the third part of the research.

3.2. Research Methods

The actions for adopting the roadmap for OGPi firms should be provided through considering the causes of BIM implementation challenges in AEC industry, as defined in part 1. In this sense, the roadmap focused on the processes necessary to deploy BIM alongside IPD for OGP industry, considering the main challenges and their causes identified in part 1, and did not concentrate on the costs and schedules for these activities. Therefore, the input data consists of literature review (theoretical documents, theory on the technology and BIM implementation approaches, standards and scientific practice that can assist in specifying the research perspective) and empirical practical information formulated by interviewees. As such, an initial roadmap was established which discussed with OGPi experts through semi-structured interviews. As a rule, the interviews had to be continued to reach the saturation and no new data to be provided in the interviews (Marshall et al., 2013), but contrary to the AEC industry and due to the fact that the OGP industry is wider and more complex, the key people involved in this industry were limited and therefore, the selection of the interviewees was exclusive.

Considering the fact that it was not possible to reach saturation, based on the recommendations in such cases, it is decided to select 40 key personnel for the interview (Mason, 2010). The interviewees were selected according to their responsibilities and/or previous experiences (Table 2) from the whole key stakeholders of the OGP industry (owner/client, general contractor and consultant, operators and facility managers). They had enough knowledge in their field of expertise and were well versed in modern construction management practices. Most of the interviewees were aware of BIM and had experience in implementing new construction management practices in their firms. However, they had no experience of working in BIM environment. The total time spent on the interviews was 490 minutes for top managers (8 person), 2060 minutes for senior managers (24 person), 550 minutes for others (8 person) and 135 minutes for two separate joint meetings, with an average value of about 77 minutes per person (Table 2). Joint meetings were conducted for presenting, discussing and finalising the results of interviews with all interviewees.

In this study, the Grounded Theory (GT) was used to analyse the data collected from the literature reviews and semi-structured interviews (Khan, 2014) and to extract the final roadmap. This theory was used as the basis for the use of Innovation Diffusion Theory (IDT). IDT is one of the most behaviour-change models that used commonly over a wide area of innovation adoption (Hong et al., 2019; Akintola et al., 2019) and argues about spreading the innovation into a new area.

Rogers (2003) defines innovation as 'an idea, practice or object that is perceived as new by an individual or another unit of adoption', diffusion as 'the process by which an innovation is communicated through certain channels over time among the members of a social system' and adoption as a decision of 'full use of an innovation as the best course of action available'. The IDT has been founded on five underpinned pillars for adoption, each with its own attributes. In order to spread the BIM in OGPi, inspired by the Innovation Diffusion Theory (IDT), five phases including awareness, convincing, decision making (implementation design), implementation, and evaluation were applied.

Table 1. Research for using BIM in various sector of OGP industry

Sector	Main objective	Domain	Reference
Liquid natural gas	Productivity improvement via integrates advanced technologies including ICT, RFID, smart tag, laser scanning, BIM and AR in real LNG construction.	Construction	Lei et al. (2014)
Liquid natural gas	Construction Process controlling through AR+BIM	Construction	Wang et al. (2014)
Oil and gas facilities	Quality improvement of operating activities via involving the operator and subcontractors during the construction phase	Construction	Bezkorovayniy et al. (2018)
Offshore oil and gas platforms	Process Optimisation of multiple offshore platforms disassembly using BIM and GIS	Demolishing	Tan et al. (2018)
Offshore oil and gas platforms	Evaluation of different decommissioning options	Demolishing	Cheng et al. (2017)
Petroleum pipeline	Corrosion prediction	Operation	Tsai et al. (2019
Offshore oil and gas platforms	BIM-base process of offshore platforms disassembly	Demolishing	Tan et al. (2017)
Offshore oil and gas platforms	BIM-based 4D simulation for mitigating noise impact on maintenance workers	Operation	Tan et al. (2019)
Offshore oil and gas platforms	Evaluation of evacuation scenarios	Engineering	Cheng et al. (2018)
Liquid natural gas	Resource allocation	Construction	Zhou et al. (2015)
Oil/Gas industry	Increasing collaboration between engineering and construction in detail	Engineering	Larson (2019)
Oil/Gas industry	Suggesting appropriate integration technology for engineering company	Engineering	Xue (2015)

Table 2. Summarized results of interview

Partner	No. of interviewee	Average experience (year)	Total interview duration (Min.)	Average interview duration (Min./Per.)
Client/Owner	6	>20	375	62.5
General Contractor	28	>15	2300	82
Operator/FM	6	>20	425	71
Total	40	17.5	3100	77.5

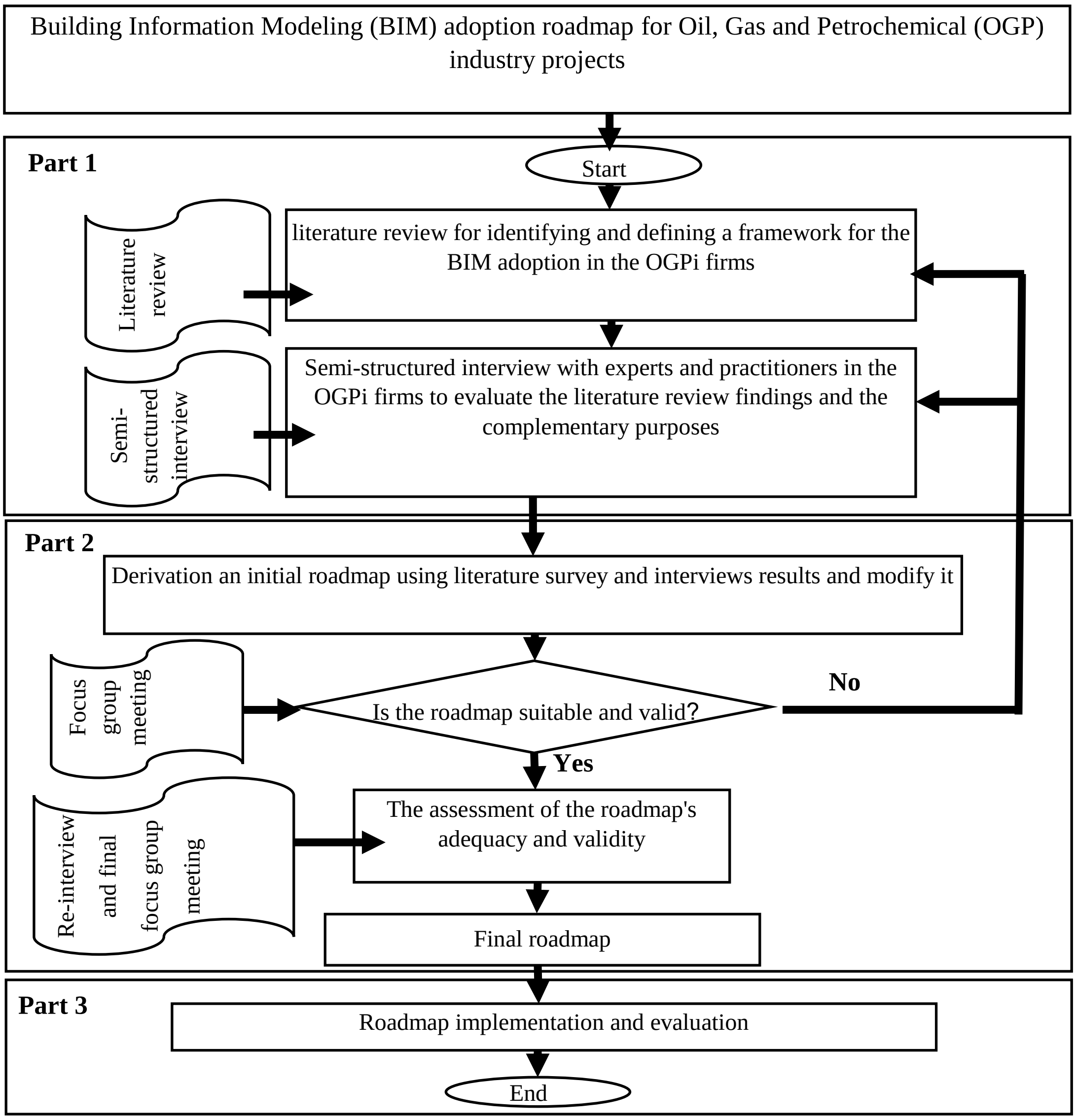

Fig. 1. Research methodology plan and process

The list of actions that should ultimately be used to overcome the challenges using Simon Sink's model, ‘Why, How, What’, is developed in conjunction with IDT (Sinek, 2009). The interviews, inspired by Sink's model, focused on why the challenges arise when managing complex projects, how to overcome them by adopting the necessary methods and actions, and what are the results of taking action. The research analysis was performed based on the confrontation between the practical and theoretical perspectives, as the assessment of the first one was based on the second one.

The final roadmap should fulfil the functional (organisational, legal, etc.) and structural specifications. The functional requirements refer to the conditions that the involved parties consider necessary for the adoption. The structural requirements are the material and intangible characteristics of the roadmap, which are necessary to meet the functional requirements and from which can be deduced (Muller, 2011). According to GT, an iterative process based on the comments from the OGPi firms' experts was set up in order to verify the findings and provide feedback for refining the findings and consequently, deriving the final version of the roadmap.

To ensure the validity of the results of this study, the triangulation including interviewing experts through individual interviews and group meetings was selected. Group meeting (focus group) is a method for collecting qualitative data. In this method, individuals participate in one or more informal group discussions about the research topic. The chairman of the focus group meeting seeks to gain access to the important experiences of the participants on the research topic in the form of a systematic and structured plan. Interaction between members of the focus group is an important and fundamental feature of this research method and makes it different from group interview, which is the interaction between the interviewer and the interviewee. In the focus group, participants respond to the views of other participants based on their experiences. This method is in accordance with the roadmap preparation method described earlier and is also in full compliance with the reflective practice method. In this regard, interviews were started based on the results of library studies and their feedback was used to refine the results. The refined results, which were the result of applying the points of view of the interviewees for each section, were assessed during focus group meetings by the following measures:

All activities and related actions that could affect the results of this research were identified and categorized through library studies and interviews. Among the categorized activities and related actions; the more relevant to the research topic were selected in the focus group meeting. At this stage, 4 fixed criteria as well as internal negotiations were used for assessment. The fixes criteria were: 1) How much does this activity contribute to the success of the roadmap? 2) Does the introduced action relate with the nominated activity? 3) Does the proposed action comply to the IDT phases and category in which it is located? 4) How sufficient are the steps for the roadmap setup? In the internal negotiations, the question of: "Based on participant's experience, is there anything else that should be considered in the preparation of the roadmap?", put in the core of negotiations.

After that, based on the group member experiences and negotiations the factors that seemed to have a small effect were removed from the list through 5-point Likert scale. To this end, each participant assigned a point of 1 to 5 to each activity and its relevant actions. A point of 1 was considered for the least effect and a point of 5 for the most effect in creating value for the roadmap. At the end, the average point of all activities and actions were calculated and all those with point below 3 were omitted. Finally, 5 activities and 24 related actions were selected as the refined results.

The refined results were re-examined through re-interviews and final focus group and the final results including 5 activities and 20 related actions were extracted from them. At this stage, 4 actions (PESTG analysis, following the current government construction strategy to define the BIM strategy set up, use of the LEED concept alongside with BIM and IPD, introducing a specific set of software) that had border point (close to 3) and were not agreed upon were eliminated. The re-interview method based on previous feedback and final focus group were used to ensure the adequacy and validity of the results. In the other words, during this interaction and iterative process, the research conclusions and recommendations were drawn and validated.

4. Results

The roadmap is generally represented as a flexible and powerful graphical display, including a multi-layer-based graph that connects different perspectives of the topic of interest in a strategic perspective view (UNIDO, 2009). A successful roadmap connects the current situation to the goals (desired situation) through the milestones, challenges and actions during a specified timeline. This study looks for the subject of BIM as incorporated in the Oil, Gas and Petrochemical industry and tries to provide an adoption roadmap for BIM deployment for OGPi firms. In the roadmap, the activities and actions are related together via the cause and effect during the desired timeline to achieve the goals.

Roadmap is a strategic and, in fact, an integrating plan which can help the planning process by considering all the important levels involved in the problem situation. The roadmap development process brings together the views of key parties. When a roadmap is developed, it can be widely used as the reference point for the communications and continuous actions (Phaal, 2015). Due to the fact that the roadmap should be defined within a timeline, the IDT phases incorporated in the roadmap were considered instead of the timeline. Therefore, to prepare a real adoption roadmap, it is sufficient to add the required time to execute each phase for the suggested final roadmap.

4.1. Current and Desired BIM Situation in OGPi Firms

Iranian oil, gas and petrochemical firms typically use a software called PDMS (Plant Design Management System) introduced by the AVEVA software company that is a 3D multi-user and multi-discipline software package for engineering, design and construction of the OGPi projects. Furthermore, few specialised software is used for the design of structure, process, piping, stress control, supports, electrical, instrument, etc., and the results are transferred to this software. Few outputs of these specialised software are interoperable with PDMS and other software outputs are manually entered into this software. Finally, the PDMS output is transmitted into the Navisworks software (Autodesk) to review the 3D model and extract possible clashes. The final PDMS model is used to prepare few procurement, fabrication and construction purpose such as drafting, material take-off, isometric drawing, spooler and so on.

According to the results of the interviews conducted in part 1, all processes among the partners' general current practices were recognised as maturity level 1 and fully or partially fragmented. The engineering practices were also recognised as maturity level 1, with trends to higher level due to the nature and required interdisciplinary checks. All the parties involved in the selected OGPi firm (owner, client, general contractor and their subsidiaries, vendors and operator) showed their interest to level up their activities. Thus, BIM level 2 was set up as the desired level.

BIM level 2 is introduced as a collaborative object-oriented model. At this level, the parties involved in the project do not necessarily work with a single unique model. Rather, they use their own three-dimensional models. The procedure of information exchange between different parties involved in the project is determined by the type of partner's cooperation, which is the critical aspect of this level. The design information is shared across the same format in the same way which enables the project organisation to combine the data of all parties in a unique 3D model and build a common BIM model. Hence, the software used by each party should be able to deliver the files to one of the common formats such as the Industry Foundation Class (IFC) format.

4.2. Milestones

Although the research does not include the implementation and evaluation phases, but it intends to generate a roadmap to enable the OGPi firms assess their organisation and projects and choose the right direction in the adoption and implementation of BIM. The roadmap derived in this study did not include a timetable. The required timeline milestones for the roadmap derived in this study were replaced with the specified phases of the innovation diffusion theory. In other words, raising awareness, convincing, decision-making (implementation design), implementation, and evaluation phases were considered as the time phases of the roadmap and their interface was considered as the roadmap milestones. In the future, to implement the roadmap in a real case, the real time could be easily installed at these interfaces.

4.3. Identified Challenges and Related Activities and Actions

Given that the roadmap marks the pathway from the current situation to the desired situation as the goal, the identification and categorisation of the challenges and related activities and actions for overcoming the challenges are the most important issues in the roadmap preparation process. To respond to all the challenges using the Sink model, a set of activities were identified each containing several actions. Identifying the activities and related actions was done according to the model shown in Figure 2. They were based on the use of conventional methods for the strategic management along with the Sink model. The list of actions is prepared using the 'Why, How, What' questions. According to this model, in order to express the actions, the first category of information to be explained is 'why' and what is our motive. The second category of information is extracted from the 'How' question and explains the methods used to carry out the actions. Finally, the third category of information answers the 'what' question and describes the purpose and final result. Using these questions, the challenges are linked to the list of expected actions and outcomes. One of the main causes as to why organisations and people who use it can successfully find their appropriate direction is that this approach is a natural way of argumentation (Sinek, 2009). Therefore, in the current research, this approach was adopted as an effective way to describe the list of actions.

To prepare the roadmap in the described manner, the challenges of BIM implementation in the AEC industry were identified through the literature review, and were categorised into processes, people and tools which are called the golden triangle of the changes. They were ultimately finalised for the oil, gas, and petrochemical industry by interviewing OGP industry experts. By finalising the list of challenges, the challenge map (Figure 3) was drawn to provide the main focus and identify the activities and actions that should be considered in the roadmap. The challenge map in Figure 3 was drawn by grouping the challenges into four categories of 'should be described', 'should be covered', 'should be explained' and 'should be provided' to be used in deriving the roadmap. It is obvious that the challenges related to 'should be provided' are more important than the others and lead to defining the outcomes.

As the roadmap is a strategic plan in context, the list of roadmap activities to be performed in this study were customised based on the required activities for implementing the strategy plan. The feasibility study for adopting BIM in OGPi firms, BIM strategy setup, establishment of leading BIM group (task group), development of BIM business model, and development of IPD-BIM collaboration protocol are the five activities considered in this way. Hereinafter in this study, these activities are referred to as S1 to S5, respectively. The highlighted point of this roadmap, which is not included in the roadmap of the AEC industry, is to pay attention to the more structured OGP industry, familiarity of OGPi with the IPD approach and IPD-BIM collaboration. The issue of BIM and IPD collaboration highlighted in the text of all activities while activity S5 has dealt to this issue specifically. To provide a list of actions to be performed for overcoming the challenges and removing the obstacles, the experiences of companies implementing the BIM technology in the AEC industry and also the results of the interviews were utilised. In addition, considering the context created for the execution of the projects in an integrated environment, focusing on the synergy that can be achieved by BIM-IPD collaboration shortens the list of actions.

Figure 3 depicts the challenge map and shows the finalised challenges where the IPD features can assist in overcoming them. It is necessary to emphasise that the methods of overcoming the challenges in any organisation are unique and dependent on the process assets and organisational culture and hence, they are not possible to be used directly. However, the experiences and actions that these companies have incorporated are categorised and used to extract the final list of actions for each activity. The final list of actions extracted based on 'Why, How, what' questions and the above-mentioned considerations can be reduced or increased depending on the maturity of the organisation. Table 3 shows the summarised results of this process. The list of activities and related actions consisting of 5 activities and 20 actions is presented in Table 4. All of the above processes were carried out on a repeated path by the specialists of the OGPi to make sure the results are reliable. Table 5 shows the distribution of the actions during the IDT phases. This table was used for directly preparing the roadmap.

4.4. Setting up the Roadmap

Considering the actions related to BIM challenges alongside the IDT phases including the awareness, convincing, decision making (implementation design), implementation and evaluation is the approach adopted in this research to formulate a roadmap for deploying BIM in the OGPi firms. To this end, the roadmap was planned with six interconnected steps to guarantee the BIM deployment in OGPi firms through performing the actions in response to the related challenges and activities. These six steps are as follows:

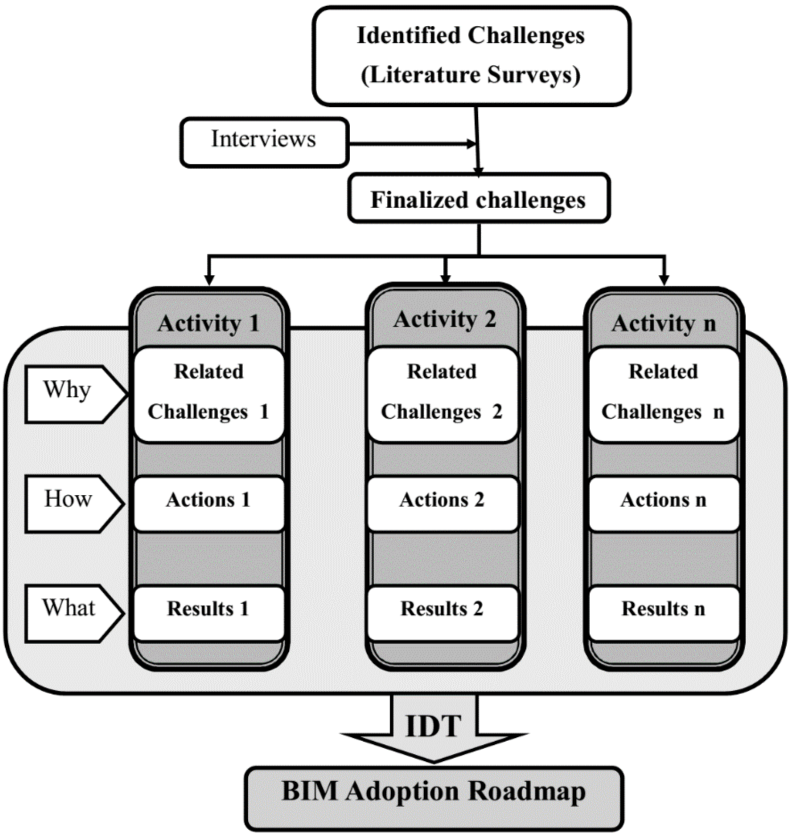

Fig. 2. Model for identification of activities and related actions

Table 3. Summarized results of identification of required actions and expected outcomes

	Why	How	What
S1	For awareness and convincing people and organization. By doing this activity, the T5, M4, P10, P5 and P1 challenges are addressed.	By analysis of the strengths, weaknesses, opportunities and threats (SOWT) of BIM implementation within the OGPi. They are achieved by actions 1 and 2.	The output of this action will be a complete and reliable analysis of the BIM capability of for successful implementation in the OGPi firms' projects.
S2	By doing this activity, in addition to achieve the intended goals including increase of cost-effectiveness of BIM implementation and creating interoperability between involved parties, theT1, M3, P10, P3, and P1 challenges are addressed.	By doing this activity, the goals of adopting BIM are established and the business strategy of the involved parties is linked to the current and future development of BIM technology. It is done by actions 3 to 5.	By setting up a BIM strategy, it is expected to achieve the following results: 1. Parties visions and missions 2. Parties strategy to achieve missions and setting goals for BIM. Principles of this strategy concerning BIM-IPD collaboration and technology interoperability.
S3	To prevent reduced motivation of members in the long term implementation of BIM process. By doing this activity, the challenges M1and P10 are addressed.	The leading BIM group is responsible for the following tasks: 1. Supervision and leadership at party-level strategy implementation 2. Ensure that the parties go in the right direction and with the right speed. 3. Defining new goals and future BIM strategy. It is done by actions 6 to 11.	1. Continuous monitoring of the BIM strategy at the parties and party level 2. Assigning resources to support creation of the required BIM structures. Support the use of BIM by all involved parties.
S4	This activity not only requires focusing on the technical and educational aspects of the process, but also should analyze to the way of integrating BIM in its business structure and how it is tailored to compete in the market. By doing this activity, the challenges T5, T2, M6, M3, M2, P12, P10, P8, P4 and P3 are addressed.	Creating a business model for implementing BIM at the level of all parties, each party will make its business model compatible with the mentioned model. It is done by actions 12 to 17.	1. Decision to adopt BIM capabilities across the entire parties and each party 2. Investing in development of the BIM skills among the key personnel in connection with the clients Creating an up-to-date business model for higher rate of market penetration.
S5	By doing this activity in addition to setting collaborative relations between and within the involved parties, the legal and contractual aspects of BIM are defined and the challenges T4, T3, T1, M5, M3, P11, P9, P7, P6, P4 and P2 are addressed.	Creating a collaborative environment in which the parties are involved at each stage of the project life cycle, the activities to be performed at each stage, and the outputs that should be attained in an integrated environment based on IPD in the context of the BIM tool has been specified. It is done by actions 18 to 20.	Providing a structural plan for collaborative use of the BIM and IPD in projects, describing the contractual and legal issues, describing responsibilities, expected outcomes, model level of details and model ownership and management are the most important outputs of this activity.

1) The leading BIM group (BIM task group) is created. The group conducts the feasibility study to apply BIM at maturity level 2, focusing on raising awareness of adopting the new technology in oil, gas and petrochemical industries.

2) The leading group sets up the BIM strategy using the results of the feasibility study carried out in the first step and appreciates the OGPi from the BIM technology and, at the same time, convinces the top management of the OGPi firms to

adopt BIM.

3) After convincing the top management of the OGPi firms and decision making in relation to the implementation of BIM, intends to develop the relevant business plan.

4) Considering the characteristics of the business plan, the BIM implementation plan including the collaborative procedures and cooperation processes are prepared. The contractual framework and the specifications of the implemented software are planned among the parties and within their organisations. In this step, the objectives of the collaboration, human resources development plan, software development plan and required resources for the support and supervision are finalised to achieve the integrity in the entire OGPi firms.

5) The BIM is implemented based on the four above steps, and

6) The BIM implementation evaluation is made based on the received feedback and necessary corrective actions.

The results of this research using the Sink model and the steps explained for the BIM implementation lead to the derivation of the roadmap for the adoption of building information modeling in the oil, gas and petrochemical industries firms.

Table 4. List of activities and related actions

	Activity	Related actions
S1	Feasibility study for adopting BIM in OGPi firms	Action 1: SWOT analysis for use in awareness and convincing of key parties. Providing situation assessment and strategic actions matrix and determination of aggressive, conservative, defensive or competitive strategies for use in convincing and decision-making phases.
S2	BIM strategy set up	Action 2: Establishing long-term goals for use in convincing and decision-making phases. Action 3: Estimating related costs for use in awareness and convincing phases. Formulating of party's interoperability principles for use in decision-making and implementation phases.
S3	The leading BIM group (task group) establishment	Action 4: Creating a BIM task group for decision making, implementation and evaluation phases. Action 5: Forming leading teams inside the community for implementation and evaluation phases. Action 6: Set up the communication line between the party's internal and external teams in order to create integrity between all parties for the implementation and evaluation phases. Action 7: Forming monitoring and evaluation teams for implementation and evaluation phases Action 8: Supporting BIM implementation in all parties involved in the project for implementation phase. Defining new goals and future development for the evaluation phase.
S4	Development of the BIM business model	Action 9: Technical studies and the determination of technology requirements in the entire parties for the decision making phase. Action 10: Industry analysis and market studies for awareness and convincing phases. Action 11: Determining the role and responsibilities of parties for the decision making phase. Action 12: Financial and economic analysis for the decision making phase Action 13: Risk assessment for the convincing and decision making phases. Updating business plan for implementation and evaluation phases.
S5	Development of the IPD-BIM collaboration protocol	Action 14: Determining how to coordinate between and within the parties for the implementation and evaluation phases. Action 15: Set up a party's interoperability protocol for decision making, implementation and evaluation phases. Establishing a standard contract format based on the BIM-IPD collaboration model for decision making and implementation phases.

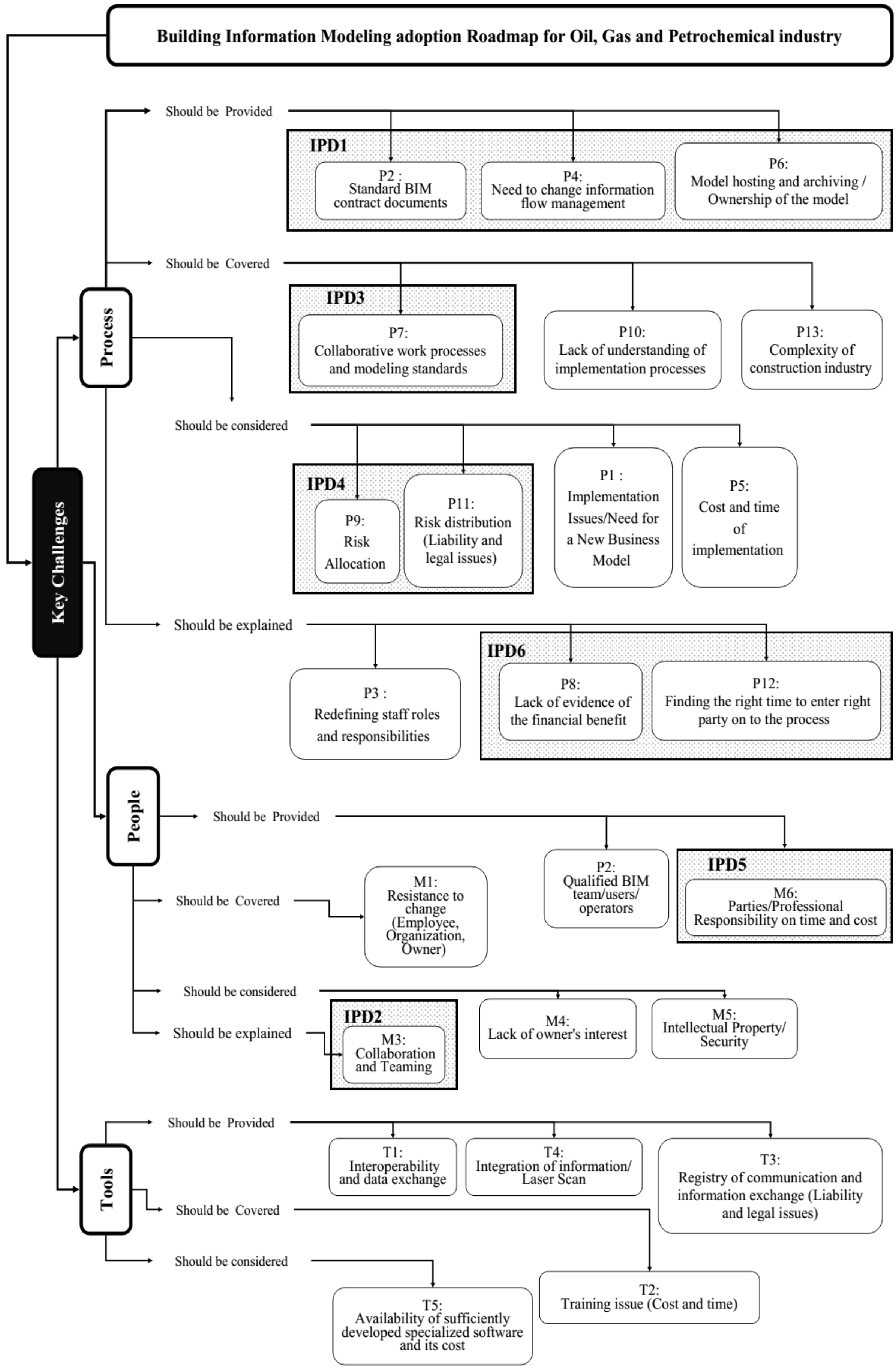

Fig. 3. Challenge map for adopting BIM in OGPi according to IPD features

Table 5. Distribution of identified challenges and related actions during IDT phases

		BIM barriers and challenges	Activity	Gu et al. (2010)	Azhar (2011)	Eastman et al. (2011)	Succar (2013)	Both et al. (2012)	Azhar et al. (2012)	Kalinichuk et al. (2013)	Ibrahim (2013)	Stanley et al. (2014)	Elmualim et al. (2014)	Risto (2015)	Actions: Awareness	Actions: Convincing	Actions: Planning	Actions: Implementation	Actions: Evaluation
Process	P1	Implementation issues	S1,S2,S3	•	•	•	•	•		•			•		1,2,3,4	1,2,3,4	5,6	5,6,7,8,9	6,7,8,9
		Need for a new business model	S4	•	•	•	•	•		•			•		13	13	12,14,15,16	17	17
	P2	Absence of sandard BIM contract documents	S5		•	•	•	•	•								20	20	
	P3	Redefining staff roles and responsibilities	S2,S4	•		•			•		•	•		•			5,14		
	P4	Need to change information flow management	S4,S5	•	•		•		•		•	•					19,12	19	19
	P5	Cost and time of implementation	S1,S2,S4		•				•		•	•	•		2	2,4	4,15		
	P6	Model hosting and archiving /ownership of the model	S5							•	•	•					20	18,20	18
	P7	Lack of collaborative work processes and modeling standards	S5				•		•			•					19,20	19,20	19
	P8	Lack of evidence of the financial benefit	S3,S4								•		•		13	13,16	15,16		11
	P9	Risk Allocation	S1,S5		•										1	1	15		
	P10	Lack of understanding of implementation processes	S2,S3,S4				•						•	•		3	3,5,20	5,8,10,20	8
	P11	Risk distribution (liability and legal issues)	S5								•		•				20	20	
	P12	Finding the right time to enter right party on to the process	S4		•									•			12,14		
	P13	Complexity of construction industry	S1				•					•			1,2	1,2			
People	M1	Inertia/Resistance to change (employee, organisation, owner)	S3			•	•	•		•		•		•			6	6,10	6
	M2	Absence of qualified BIM team/users/operators	S4						•	•	•		•	•			12,14		
	M3	Collaboration and teaming	S2,S4,S5		•	•	•		•							3	3,5,19	5,18,19	18,19
	M4	Absence of owner's interest	S1		•					•	•	•			1	1			
	M5	Intellectual property/security	S5	•	•				•		•						20	20	
	M6	Parties/Professional responsibility on time and cost	S4						•	•							14	17	17
Tools	T1	Interoperability and data exchange	S2	•	•	•	•	•	•		•	•		•			5	5	
	T2	Training issue (cost and time)	S2,S4	•				•	•		•	•	•	•		4	4,15		
	T3	Registry of communication and information exchange	S5	•					•								19,20	19,20	19
		Integration of information/Laser scan	S5		•	•			•								12,19	18,19	18,19
	T5	Availability of sufficiently developed specialized software and its cost	S1,S4										•	• •			4	4,12	

4.4. Research Limitations

The limitations of this research are as follows:

1) The lack of real cases that have implemented the BIM in the OGPi firms mandated this research to inspire the experience of the AEC industry in this regard.

2) Normally, any roadmap should contain a timeline for its implementation. However, given the limitations, the present roadmap for adopting BIM technology in the OGPi firms was replaced with IDT phases.

5. Findings

The findings of this research are as follows:

1) The utilisation of BIM in AEC industry projects has been well developed so that today, all the developed and developing countries implement or plan to deploy BIM in their building projects.

2) The studies on the situation of the AEC industry have shown that BIM has greatly contributed to the improvement of the industry. However, it has not yet been able to fill the gap between the productivity and efficiency of this industry and the other industries.

3) The oil, gas and petrochemical industry has been utilised the integrated project delivery method to achieve the productivity and efficiency improvement. However, IPD cannot solve the problems of this industry, especially the island functions, and lack of integration in the process, people and tools. Therefore, to overcome the existing challenges, it is necessary to adopt a complementary project management approach that can correct this defect.

4) BIM and IPD have a synergistic role for each other which can correct the defects of each other. Through the creation of standard contractual formats for IPD and BIM, the AEC industry has overcome many challenges of the BIM and has proven its positive role in this respect.

5) The oil, gas and petrochemical industry has sufficient incentive to implement the BIM in collaboration with the integrated project delivery methods. However, due to the lack of any research and proven experience as well as the breadth of the industry, a roadmap for adopting BIM in the OGPi firms should be derived to avoid repeating the mistakes experienced in the AEC industry and achieve the established benefits of BIM.

6) In order to draw up an appropriate roadmap, the existing situation of an Iranian oil, gas and petrochemical industry firm was analysed and a set of necessary activities and actions were proposed hereupon. Given the more suitable situation of the OGPi firms in the developed countries, this is a conservative roadmap in these countries.

7) The roadmap was derived using the standard principles of preparing strategic plans (Figure 4). It depicted all the needed actions that should be adopted at the process, people and tool levels at different IDT phases in accordance with the given deployment steps.

8) The roadmap should be prepared with a real timeline for actions in Iran using the support of the government as the main owner of the oil, gas and petrochemical industry, and then the implementation plan for BIM in this industry could be finalised.

9) The effective and efficient BIM-IPD deployment in OGPi firms requires some incentives such as the government support, publication of BIM–IPD requirements and guidelines, growth of demand for BIM-IPD projects, development of IT infrastructure capabilities, widespread global support of the BIM-IPD and finally, mandated use of BIM.

6. Conclusions

Adopting BIM alongside IPD was investigated in this study in an effort to reduce the waste, costs, time and materials, and increase the efficiency and productivity of the OGPi projects. The results of the present research showed that despite the fact that the process, people, and tool platforms in OGPi were more established than the AEC industry, there were no significant effects of implementing BIM in the oil, gas and petrochemical industry. The study, therefore, aimed to provide a roadmap for adopting BIM alongside with IPD for oil, gas and petrochemical firms (Figure 4) through literature review, semi-structured interview and focus group meetings. The highlighted point of this roadmap, which is not included in the roadmap of the AEC industry, is to pay attention to the more structured OGP industry, familiarity of OGPi with the IPD approach and IPD-BIM collaboration. Finally, the roadmap was derived via inspiring by a few models and approaches. The innovation diffusion theory, 'Why, How, What' questions (Sink model), strategic planning and innovation roadmap as well as the triangulation method through iterative process between literature review, interviews and focus group meetings were used to directly derive the roadmap and its key elements. Triangulation was used to ensure the validity of the final roadmap.

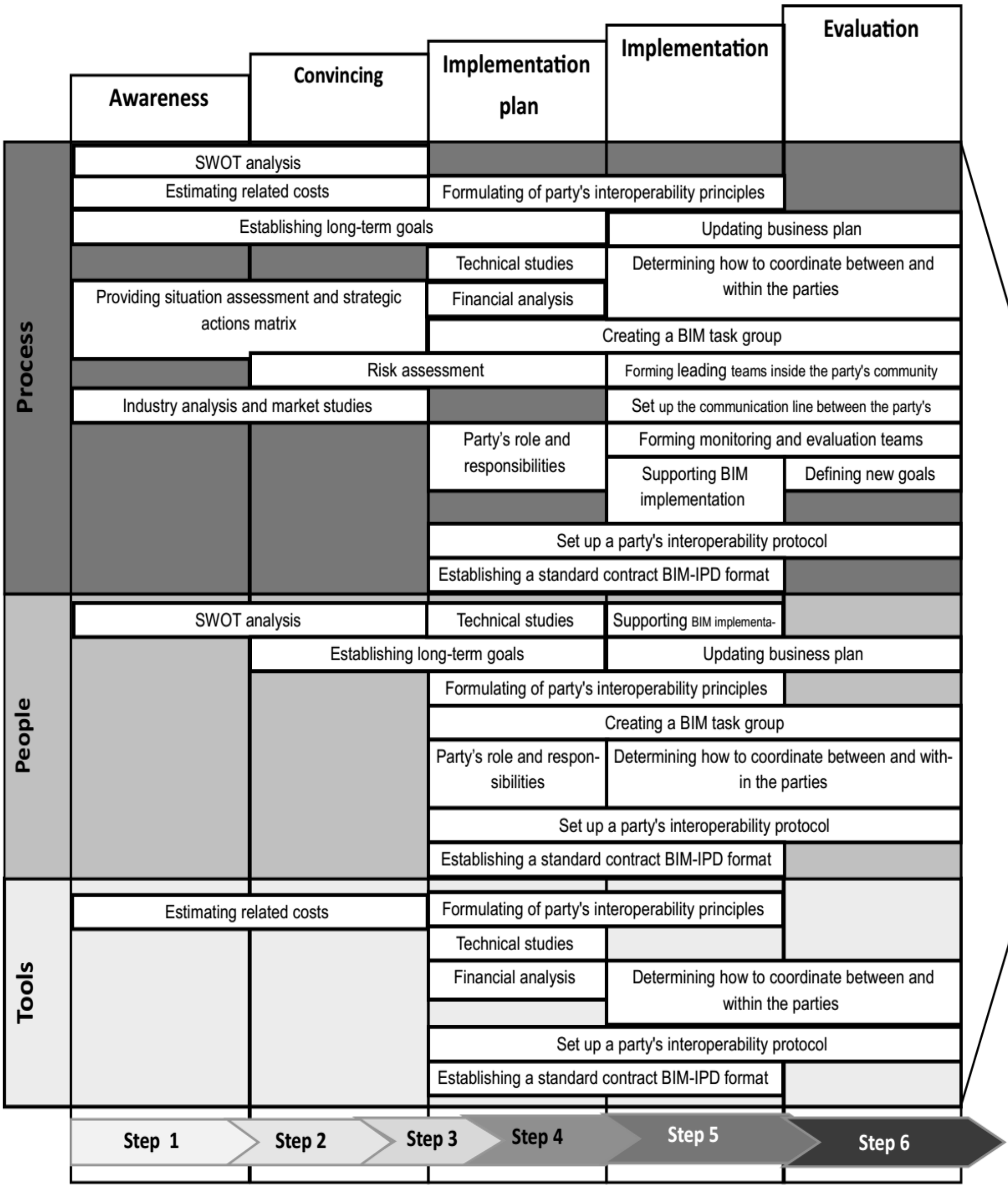

Fig. 4. BIM adoption roadmap for oil, gas and petrochemical industry

Given the time constraints and the scope defined for this part of the research, the implementation and evaluation phases of the roadmap were not considered and postponed to the future subsequent research. The activities and actions identified in this research may vary in a real case based on the OGPi firm's process assets and organizational culture. However, in the continuation of this research, the roadmap could be utilized to prepare a specific detailed roadmap for the Iranian OGPi firms or any other country that would wish to introduce the new managerial approaches to this industry. In this regard, given the compulsion of British construction companies, this country could also be among the target countries for the continuation of this research and preparation of a detailed specific implementation roadmap. Other new managerial approaches such as Lean Construction could also be merged into the roadmap.

7. Geolocation Information

This research was conducted to prepare a roadmap for BIM implementation in the oil, gas and petrochemical industry based on international experiences of BIM implementation in the architectural, engineering and construction industry. In this study, in addition to the international references, the semi-structured interviews were used. The experts selected for the interviews were chosen from Iran.

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