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A novel framework for planning policy and responsible stakeholders in industrial wastewater reuse projects: a case study in Iran

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ABSTRACT

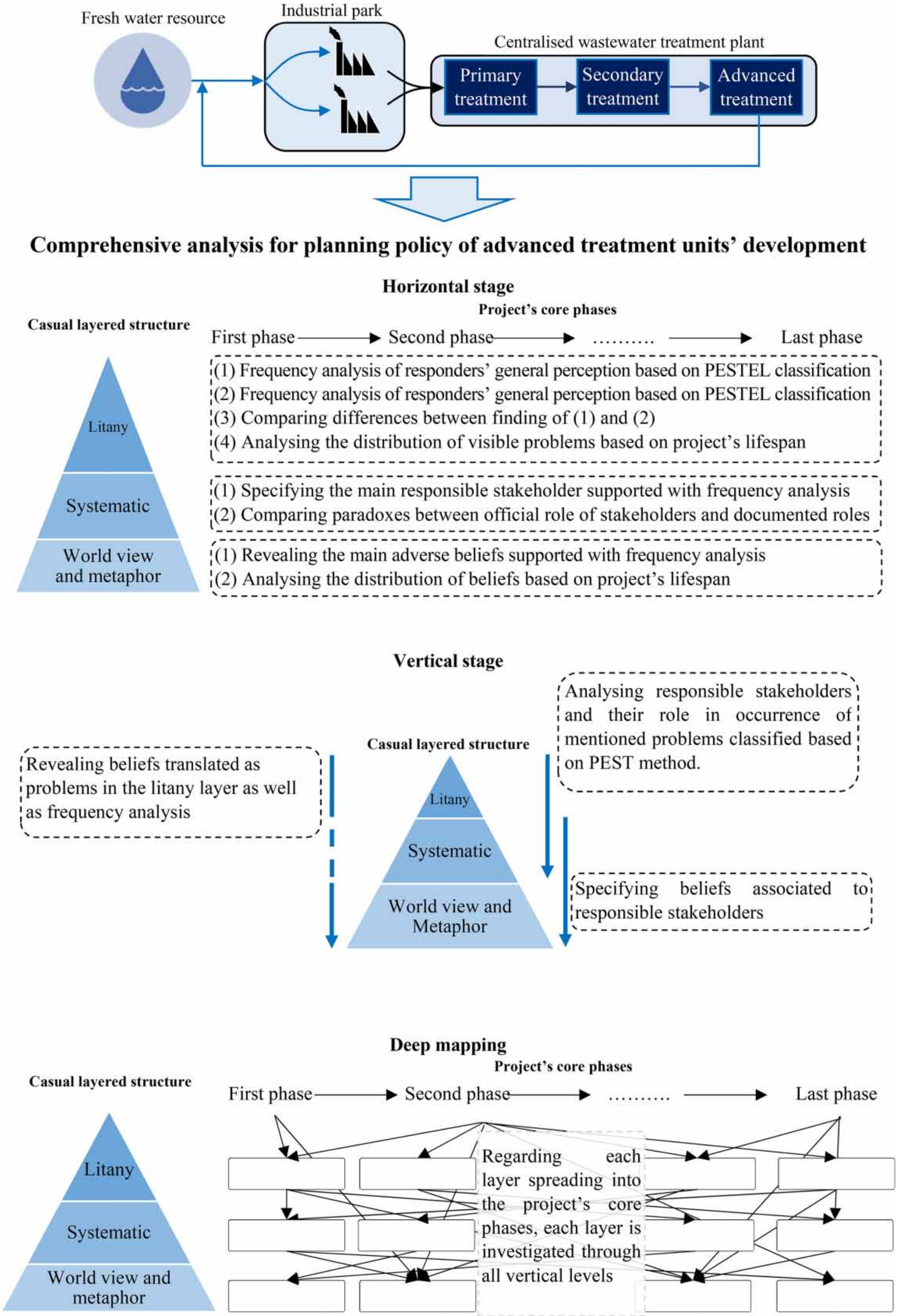
Industrial wastewater recycling projects are mainly used for alleviation of both water scarcity and contamination of freshwater bodies. These projects mainly address major challenges related to technological and economic aspects rather than stakeholders' responsibility. Hence, little is known for the role of responsible stakeholders as a major part of planning policy, which requires recognition of their crucial role and integration into associated procedures. This paper presents a new decision support framework to identify responsible stakeholders and reveals the role of their motivations. The approach integrates qualitative and frequency analysis methods into a comprehensive framework to identify the problems over the project lifetime from visible to their roots and link them together with stakeholders through deep mapping. The planning policy framework is applied to a real-world case study of industrial parks in Iran. The results of the case study show that visible economic, social, and technological problems are caused by responsible stakeholders with no direct role in those projects. Additionally, deep mapping analysis shows various deep roots caused by the government and industry are linked to visible problems across all project phases that are related to the role of stakeholders, their behaviour, and deep beliefs.

Key words: Causal layered analysis, Industrial wastewater treatment, Planning policy framework, Responsible stakeholders

HIGHLIGHTS

- A new planning policy framework is developed for industrial wastewater reuse projects.
- Visible problems, responsible stakeholders, and their beliefs are identified within a project.
- Visible problems, stakeholders, and beliefs are interconnected through deep mapping.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Today, water resources in many parts of the world are under increasing pressure from irrigation-based food supply, increasing urban water demands, and industrial growth especially in semi-arid and arid areas where water plays a vital role for their development, national economic growth, and the environment (Cossio *et al.*, 2020). Among all water users, providing industrial water is crucial as lack of access to water resources may stop valuable economical productions. Furthermore, industrial wastewater is another major concern due to the contamination of untreated wastewater discharged into receiving water bodies (Piadeh *et al.*, 2014). Therefore, recycling industrial wastewater is a practical sustainable solution that can both provide accessible water and prevent contaminating freshwater bodies (Piadeh *et al.*, 2018a).

Nowadays, combining advanced treatment units (ATUs) with conventional treatment processes can result in less contamination in treated effluent (Naghedi *et al.*, 2020). Despite benefits of integrating these advanced technologies, stakeholders are sometimes reluctant to develop these units based on their own preferences and due to the complexity and uncertainty of reliability assessment in these ATUs and hence, overlook this scheme within the planning phases. As planning any wastewater reuse scheme needs active engagement of relevant stakeholders, the lack of appropriate involvement or having negative views on decision-making, design, construction, and operation phases may lead to a failure of these schemes over a long-term period (Salgot & Folch, 2018).

Several studies investigated the stakeholders' behaviour and their motives for being against the ATU development. For example, Ba-Alawi *et al.* (2020) analysed man-made incidents and faults in the ATU equipment. Piadeh *et al.*, (2018b) also analysed consultants' faults for design and contractors' failure in construction. For studies analysing environmental and economic risks, stakeholders were considered only as investees or investors (Hernández-Chover *et al.*, 2018). Some studies limited the role of stakeholders in end-users views to support recycled wastewater or willingness to pay tariffs (Dalhat Mu'azu *et al.*, 2020). Additionally, some studies only analysed the role of policymakers in strategic decisions such as increasing tariffs or environmental regulations to motivate ATU developments (Buzuku *et al.*, 2015). Some studies also analysed the role of stakeholders as public acceptance, number of stakeholders participating in the development, number of new jobs created and health risk in sustainability assessment criteria (Cossio *et al.*, 2020). In relevant studies including abovementioned ones, the role of vital stakeholders was almost neglected and consequently, the main intention of interruption due to the stakeholders involvement were not studied properly. Hence, the main objective of this paper is to develop a new framework to analyse the role of relevant stakeholders and their motives for reusing treated industrial wastewater, which is raised from the following three research questions (RQs): (RQ1) Which associated responsible stakeholders influence ATU projects and how they can be identified? (RQ2) What type of visible problems are caused by responsible stakeholders and how these problems can be distributed among the different processes of ATU projects? (RQ3) Is there any connection between deep beliefs of responsible stakeholders and associated problems?

To address these questions, the framework in this study aims to analyse stakeholders, futurology techniques and deep mapping as qualitative analysis to (1) identify relevant stakeholders and their role in different phases in an ATU project, (2) determine responsible stakeholders for relevant system failure and identify their motivations, and (3) map all levels of problems across the different phases of the project. Furthermore, frequency analysis is used to provide quantitative analysis. A comprehensive analysis developed in this study compares all identified problems, associated stakeholders. Additionally, the framework provides a vertical comparison between the connection of problems with responsible stakeholders and links all these analyses together through deep mapping. The next section describes the proposed methodology followed by its demonstration to the real-world case study. The results are then discussed, and key findings are finally summarised.

2. METHODS

The proposed framework of this study as shown in Figure 1 contains three main steps to assess the role of responsible stakeholders in industrial wastewater reuse projects. Step 1 applies a method to identify the project phases over the project lifetime, key stakeholders, and their distribution over each phase of ATU projects. Step two entails identifying visible problems at various layers, connecting these problems to responsible stakeholders and investigation of their deep beliefs. Step 3 finally demonstrates a comprehensive analysis including deep mapping for all layers and stakeholders over the lifetime of ATU projects. Note that the proposed methodology is generic that can be applied to similar ATU projects all over the world. Having said this, the proposed method is demonstrated in Section 2.4 by its application to a real case study of industrial wastewater reuse projects in Iran.

2.1. Step 1: stakeholder identification

The aim of this step is to specify the distribution of stakeholders across different project phases as the input of next steps and form a map to show how stakeholders with their roles are connected to core phases over the project

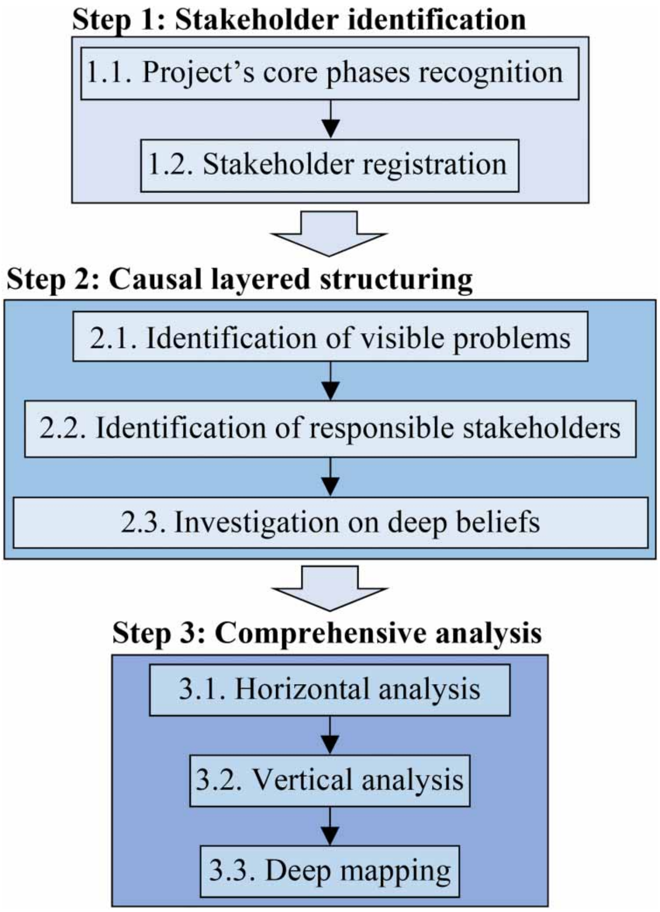


Fig. 1 | Proposed framework in this study.

lifetime. This needs different phases are clarified over the project lifetime (in Section 2.1.1) and then the stakeholders are associated with each phase (in Section 2.1.2).

2.1.1. Recognition of the project phases

Core phases defined in a project based on the primary goals can be recommended in four parts of 'planning', 'design', 'construction', and 'operation' (PMI, 2017). Core phases are compiled from official documents such as project charts, procurement documents, organisational process assets, regulation and laws, or internal instructions (Lalmi *et al.*, 2021).

2.1.2. Types of stakeholders

This step entails identifying people, groups, experts, and organisations that could impact or be affected by a decision, activity, or outcome of the project (Alcon *et al.*, 2014). Stakeholders here are classified as primary and secondary categories based on the stakeholder theory widely used in the literature (Gherghel *et al.*, 2020). The primary stakeholders are identified as those in the institutional positions with relevant roles dedicated across core phases based on official documents or administrative procedures. The secondary stakeholders with their roles can also be identified by the judgment of experts, i.e. primary stakeholders (Bendtsen *et al.*, 2021).

2.2. Step 2: causal layered analysis

This step aims to list all the problems considered as obstruction of ATU developments through identifying a range of visible problems to their deep roots, i.e. the causal layered analysis (CLA) method. Figure 2 shows the hierarchy of the CLA to clarify problems widely applied to a range of topics in the projects and find solutions influencing possible future scenarios positively (Miremadi, 2020). Three main layers of the CLA include the following: (1) the visible problem layer (also called litany layer) representing the conventional perception of problems that seems obvious and visible; (2) the responsible stakeholders layer (e.g. systemic layer) representing social explanations of events, issues and problems documented in the visible problem layer. This layer also explores the roles of stakeholders responsible for occurrence of problems; (3) the deep belief layer (the worldview and metaphor layers) seeking values, assumptions, discourses, ideas, and more importantly deep beliefs of responsible stakeholders that cause visible problems but not necessarily consciously happen.

2.2.1. Identification of visible problems

The visible problem layer is based on the problems identified through questionnaires/interviews by selected responders and strengthened by evidences from the project documents or site visits. All identified stakeholders in step 1 should introduce a representative called a responder to participate in an interview. The major problems can be classified under more sub-classes for better analysis. This classification is based on how

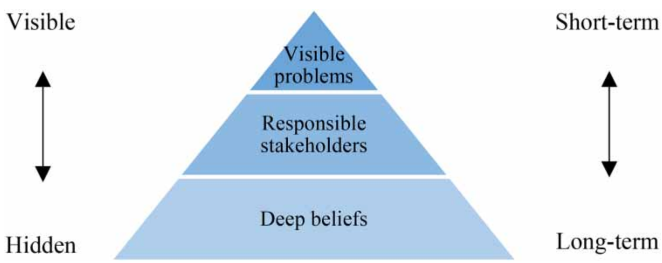


Fig. 2 | Structure of CLA defined to classify problems, stakeholders, and their deep beliefs.

decision-makers and experts are familiar to. However, the PEST framework is recommended here due to its ability to the holistic illustration of the current situations (Thakur, 2021). In this framework, all problems are divided into the four categories: (1) political problems at national, international and regional scales or regulations, which impact on developing ATUs negatively, (2) economic problems, e.g. lack of financial mobilising, lack of allocated budget, budget cuts or requiring extra costs, (3) social problems, e.g. lack of proper management, individual wrong behaviour or managers' personal preferences, (4) technical problems, particularly technological gap, maintenance issues and accessibility to desired equipment (Ahmadi *et al.*, 2016; Naghedi *et al.*, 2020).

The responders first need to raise the most challenging problem representing the main influential factors of improper ATU's development. Each responder is then asked to scrutinise the challenges in detail via (1) describing the problem, (2) classifying the type of the problem based on the PEST classification, (3) specifying the occurrence of the problem among all core phases of the project (step 1.1), and (4) classifying all identified stakeholders under primary and secondary stakeholders (step 1.2). All identified problems are then clustered based on their similarities and the visible problem layer is finally formed.

2.2.2. Identification of responsible stakeholders

This layer identifies responsible stakeholders and their role in the project components over the project lifetime. For this purpose, each identified visible problem is assigned to a focus group with members from all relevant stakeholders. These focus groups describe relevant visible problems and their associated responsible stakeholders in which all responders are agreed through a qualitative Delphi technique (Cheng *et al.*, 2019). The output of this step is 'specified responsible stakeholders' agreed by all responders.

2.2.3. Investigation on deep beliefs

Deep belief in here refers to the strong belief of stakeholders as the best way to manage or run the project. This can also reflect the understanding, knowledge, and experience of stakeholders for dealing with the project within all phases of the project including planning, design, construction and operation. Extracting deep beliefs is a challenging process mainly because it is subjective and discussed in the social sciences (Farrow, 2019). Here, responsible stakeholders are interviewed individually to find out their views and deep beliefs which consciously or unconsciously prevent developing the ATU projects. Furthermore, it is recommended that specialists in various fields such as psychology, sociology, economy, management, philosophy, theology, political science, and history assist the interview to understand the deep beliefs of responsible stakeholders.

2.3. Step 3: comprehensive analysis

Step 3 is the comprehensive analysis through the CLA based on both quantitative and qualitative analyses by using horizontal and vertical analysis, and deep mapping. The horizontal analysis can provide details of each layer throughout the project lifetime (core phases) to realise the distribution of the problems, associated responsible stakeholders and their beliefs (Figure 3(a)). Hence, the horizontal analysis aims to (1) provide frequency analysis of visible problems, associated responsible stakeholders, and their deep beliefs and (2) demonstrate the distribution of findings throughout the core phases. Regardless of the ATU project lifetime, interactions between different layers are evaluated by vertical analysis (Figure 3(b)). These interactions link (1) the visible problems level to the responsible stakeholder layer, (2) the responsible stakeholder layer to the deep beliefs layer, and (3) the visible problems layer to the deep beliefs layer. Deep mapping shows how layers and divergent phases of the ATU projects are linked together and demonstrates how visible problems can be interconnected with responsible stakeholders and sequentially any hidden beliefs behind them.

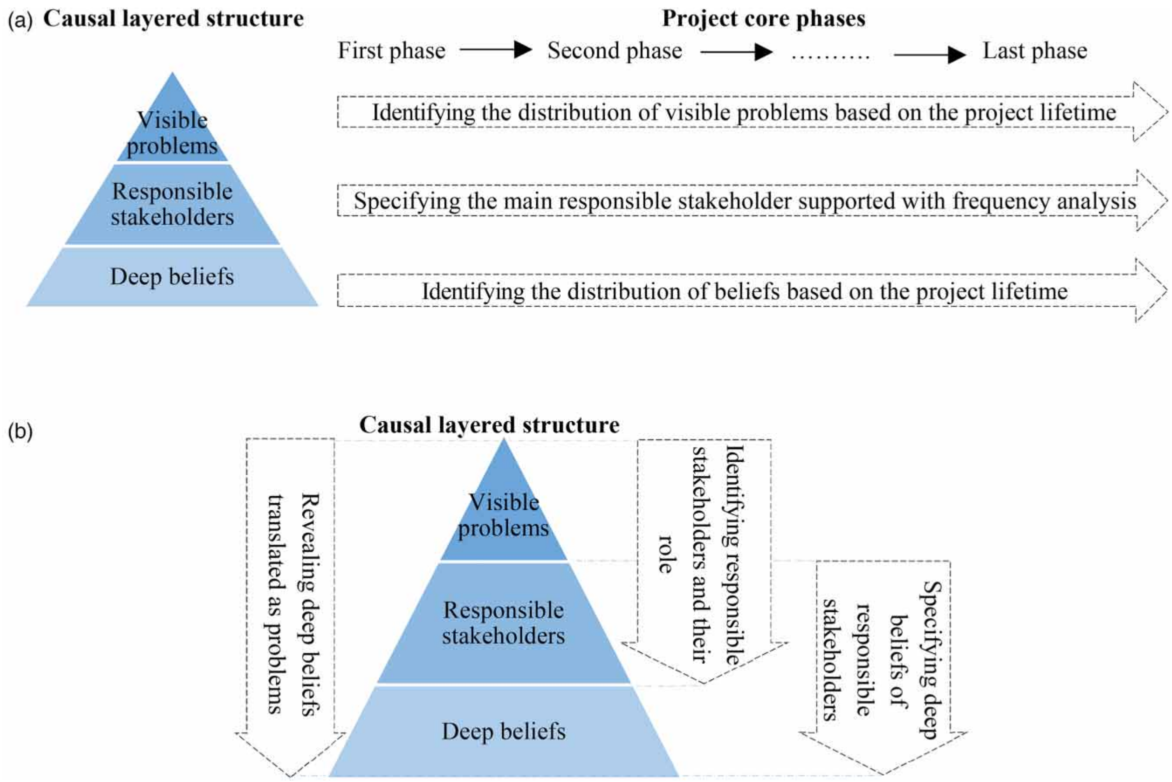


Fig. 3 | Schematic representation of comprehensive analysis in (a) horizontal stage and (b) vertical stage.

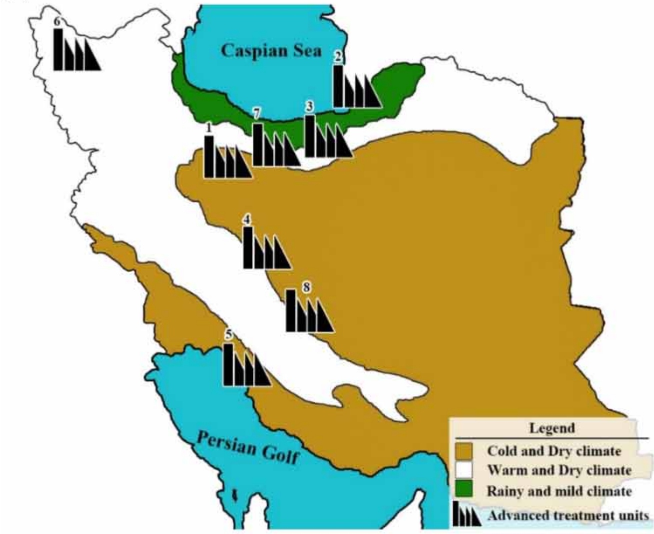
2.4. Case study

The above methodology is here demonstrated through its application to real-world case study of industrial wastewater reuse projects located in industrial parks in Iran. The parks are mainly based in semi-aired regions suffering from a lack of industrial water access (Naghedi *et al.*, 2020). Despite using only 6% of the total water demand, there are major challenges to supply this demand in these regions. Besides, untreated industrial wastewater can negatively affect both human health and the environment due to highly toxic contaminants (ISIPO, 2021). Therefore, industrial wastewater reuse has been highly recommended over the last decades as a practical sustainable solution to recover treated wastewater as a new water resource and minimise discharging contamination into freshwater bodies (ISIPO, 2021). While the initial plan was to treat wastewater by secondary processes and reuse it for landscape consumption (for 62 out of 187 industrial estates), the updated plan was to expand the treatment by using ATUs for reusing treated wastewater for industrial purposes such as supplying cooling towers (Figure 4). Despite the above strategic plan in Iran, only eight ATUs, accounted for only about 4% of the total treated wastewater, is currently operating with the updated plan as shown in Figure 4(a) (ISIPO, 2021). This can be mainly due to facing many problems posed all over the project lifetime. These problems are analysed in the following within three steps outlined in the above methodology.

3. RESULTS AND DISCUSSION

The analysis started off with reviewing official documents such as procurement documents of ATU construction and operation, consultancy, and plant monthly reports of ATUs' operation to identify the core phases of the ATU

(a)



Code	Name	Q (m^3/day)	Design year	Operation year
1	Shokuhiye	300	2008	2010
2	Aq-qala	170	2008	2010
3	Semnan	350	2008	2011
4	Murche khurt	1000	2010	2012
5	Bushehr 2	300	2010	2012
6	Shahid Salimi	600	2012	2015
7	Abbas-abad	1000	2016	2020
8	Razi	1000	2016	2020

(b)

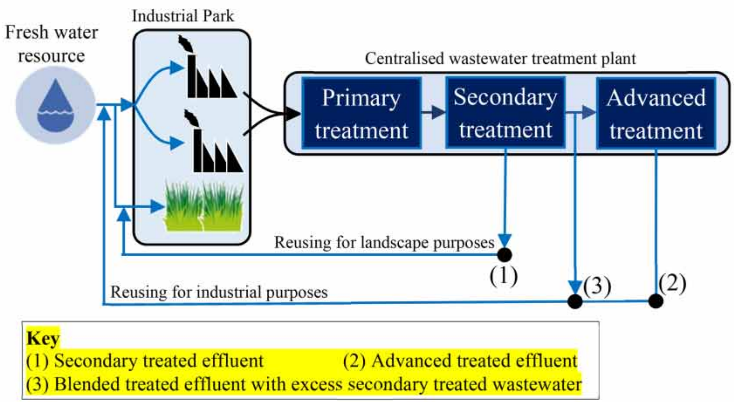


Fig. 4 | Industrial wastewater reuse projects in the case study: (a) layout of the projects with key features and (b) schematic flow diagram of the water cycle and reuse in these projects.

plants and associated stakeholders as illustrated in Figure 5 with more details in part A and Figure S1 in the online supplementary material. Further to contacting the stakeholders, 78 responders agreed to participate in the interview listed in Table S1 in the online supplementary material. Each responder first filled out a questionnaire and then participated in a meeting held for focus groups based on the details outlined in the methodology. The results of causal layered structure are reported in Table S2 in the online supplementary material. The comprehensive analysis including horizontal, vertical, and deep mapping are discussed in the following sections.

3.1. Visible problems

Table 1 shows the result of the PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) method by using the input from the responders to identify the visible problems. Out of the six categories in the

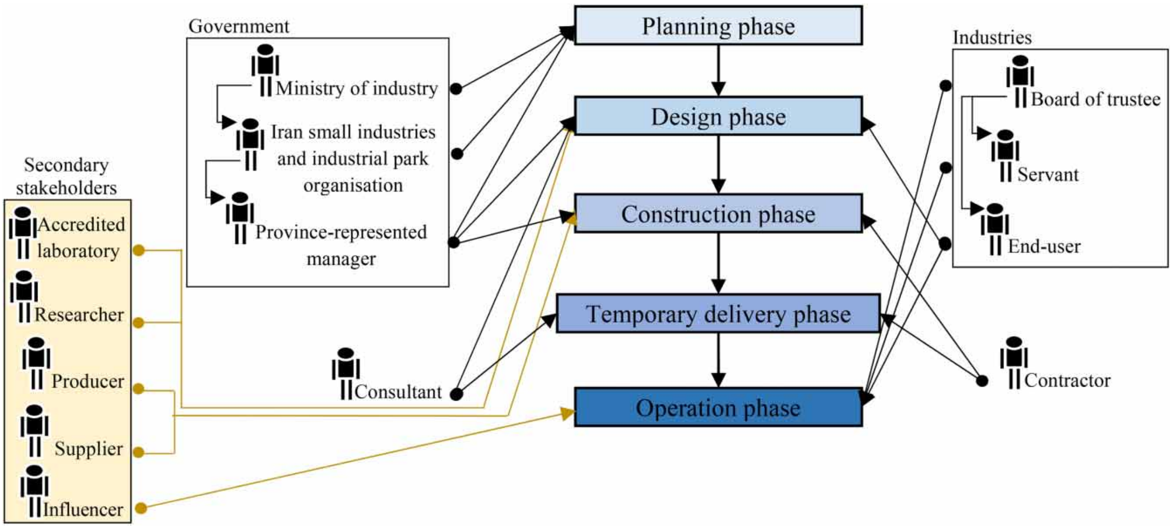


Fig. 5 | Identified stakeholders and distribution of their role in the core phases of industrial wastewater reuse projects.

Table 1 | Responses and classification of problems based on the PESTEL method.

PESTEL components	Number of general perceptions	Number of mentioned problems	Total number of visible problems
Political	3	0	0
Economical	35	98	3
Social	23	338	11
Technical	17	310	10
Environmental	0	0	0
Legal	0	0	0
Total	78	746	24

PESTEL method, the responses for number of general perceptions, total identified problems, and number of total visible problems are classified under four categories including political, economic, social and technical components. Although responders initially stated in the questionnaires that economic component is the major issue preventing the development of ATU systems for treating industrial wastewater, the major issue was then moved to the social component followed by technical component in practice, when responders analysed all problems in detail within the focus group meetings. This may show that responders tended to see all the problems in the shape of economic, especially because lack of budget resources are always raised by the government. Furthermore, this comparison shows that the main nature of problems hindering the proper development of ATU systems can vary from economic to social aspects when they are analysed in detail compared to when they are only based on general perceptions. Therefore, it seems that scrutiny of the project problems can lead to clarify the real source of the problems at the litany layer.

Figure 6 shows the results of the horizontal analysis (i.e. through the core phases of the projects) for all visible problems. The results imply that the distribution of the visible problems is inconsistent at different phases. More

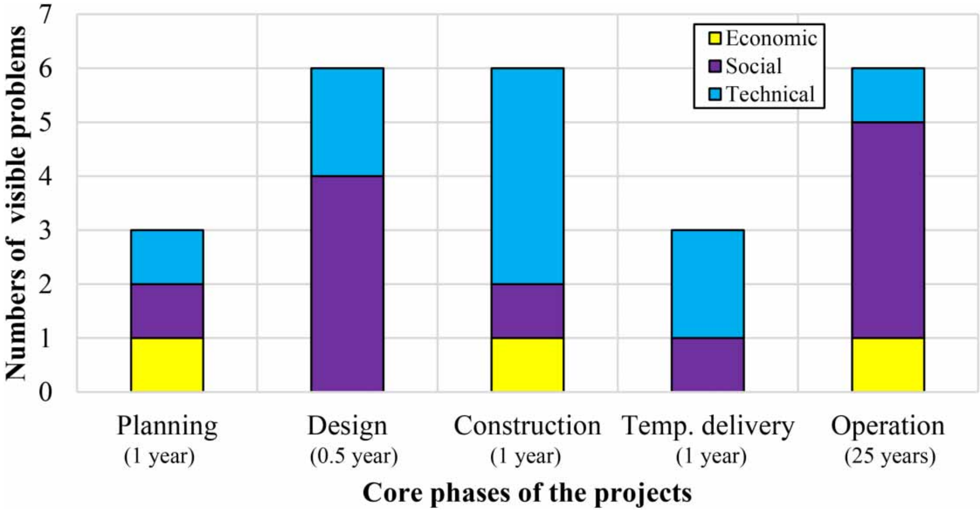


Fig. 6 | Numbers and distribution of identified visible problems.

specifically, majority of more visible problems are related to design, construction, and operation phases compared to planning and temporary delivery. Besides, while a large proportion of problems in design and operation phases are related to social problems, construction phase predominantly has technical issues. However, economic problems seem to exist as a minor issue in planning, construction, and operation phases.

On the other hand, although the same number of problems is reported for design, construction, and operation phases, it seems that the design phase is more vulnerable and plays a vital role in delaying the ATU projects especially because the six mentioned visible problems occur in only six months whereas the duration of construction and operation phases are a year and up to 25 years, respectively. Therefore, social problems in the design phase seem to be the most critical ones. More details of these problems reported by the focus groups include: (1) qualified consultants are not used or there is lack of qualified one or those hired are unable to design the plant properly, (2) lack of international consultants in the projects that are qualified for the design, (3) lack of access or use of recent practical national researches or neglecting them, and (4) lack of hiring accredited private laboratories to enhance the results and hence declining the errors, and instead using limited parameters with a large uncertainty for ATU's design. In other words, identified social problems in this part are mainly related to avoiding or neglecting qualified or accredited stakeholders that can provide more accurate design plans.

3.2. Responsible stakeholders

Figure 7 shows the results of the identified stakeholders and their distribution throughout the lifetime of the projects. As can be seen, the government is responsible for 40% of the total number of identified stakeholders causing the visible problems. Furthermore, unlike the results of stakeholder registration obtained in step 1 (stakeholder identification), responders reported that the government, industries, and politicians are responsible for some problems in which the government has no official role (blue dots in Figure 7). This finding is a crucially important that reflects problems which cannot be addressed through common existing channels relying heavily on official roles or official procedures. In other words, while normal and contractual procedures such as claiming processes or official meetings can be sought when problems appear between different stakeholders, these tools cannot resolve the outstanding problems because responsible stakeholders have no official roles. Thus, this viral

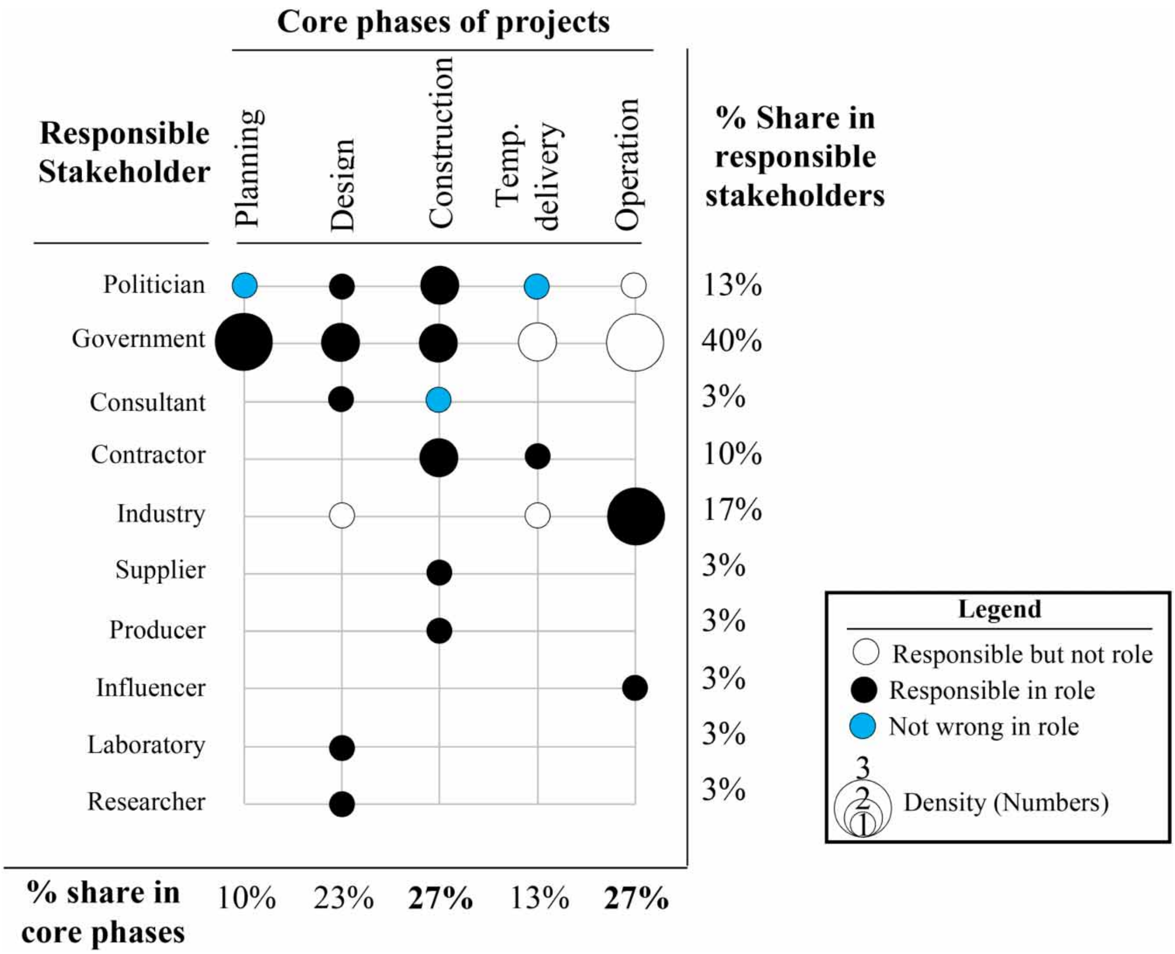


Fig. 7 | Distribution of stakeholders within the core phases of the projects. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/wp.2022.078.

points, i.e. where stakeholders are responsible for visible problems but have no official role, should be carefully extracted to find future innovative solutions such as designing win-win scenarios for the cases where all responsible stakeholders obtain the partial desired benefits.

Besides, the results show that the stakeholders are responsible mostly in the construction and operation phases, which means problems in these phases are carried out by more diverse stakeholders. This is crucial as when more responsible stakeholders are engaged in one phase, finding a solution needs more agreements upon all stakeholders, which results in a more complicated situation with harder conflict resolution. Therefore, the construction phase involving six responsible stakeholders and contains 27% of total stakeholders, is recognised as a critical core phase of the ATU projects. However, this may not be compatible with general perception of stakeholders about the most critical core phase, in which design operation phase is introduced by initial perception (see Table S3 in the online supplementary material). This can show that how deep analysis of ATU's projects through scrutinising responsible stakeholders can reveal actual role of these stakeholders and clarify impact of their role in finding critical core phase of ATU projects.

3.3. Deep beliefs

Based on detailed interviewing with responsible stakeholders, ten main reasons were extracted as 'deep beliefs' of responsible stakeholders that cause visible problems (Table 2). Figure 8 illustrates the distribution of these beliefs throughout the core phases. As can be seen, presence of 'no long-term planning' belief, reflecting a lack of attention to/analysis of possible future scenarios, consequence of wrong decisions or selections, is spread all over the project core phases and accounted for 23% of total identified deep beliefs. Additionally, four other beliefs (i.e. 'no systemic planning', 'individualism criteria', 'lack of trust', and 'adherence to anti-value') are in place for four out of five phases. Therefore, a large share and distribution of these beliefs for developing the ATU projects can be translated into complex situations and hence obstacle with numerous visible problems. Furthermore, the design phase stands alone for 35% of total identified deep beliefs closely followed by the construction and operation phases. Besides, almost all revealed beliefs occur in the design phase which are more severe than other phases.

3.4. Comparison of different layers

While the visible problems are usually easier to identify in comparison to deeper layer such as responsible stakeholders, correlation between these layers shows connections between frequency or type of visible problems and different stakeholders, as illustrated in Figure 9(a). Out of all responsible stakeholders, only the government and industry are responsible for all three types of visible problems (i.e. economic, social, and technical) while politicians and contractors are reported mainly for social and technical problems. Other stakeholders are recognised as responsible for only one type of visible problems. This shows that while a few stakeholders may cause diverse forms of visible problems for the process of ATU development, some others can be easily identified for one specific type of the visible problems. For example, consultants, influencers, laboratories, and researchers

Table 2 | Identified deep beliefs for the case study.

Code	Title	Definition
B1	No systemic approach	No clear understanding about nature of problems, relationships and interactions between the components and no analysis to obtain a reasonable solution.
B2	No long-term planning	Lack of attention to/analysis of possible future scenarios, consequence of making wrong decisions or selections.
B3	No flexibility with criticism	No capacity for critical thinking and accepting reasonable recommendations and no belief in meritocracy based on skills and abilities.
B4	Individualism criteria	Focus on individual achievements instead on quality-oriented or plan-oriented criteria to select staff with the highest ranked occupational efficiency
B5	Sense of being wiser	Superior feeling and top-down/hierarchy vision because of believing in having higher educational level or position in comparison to knowledge or experience
B6	Lack of trust	Existing long history of penalising and wrong activities that ruin trusts
B7	Westernisation	Believing in foreign activities, equipment, or any related issues without any reasonable evidence
B8	Pan-Iranism	Superiority thinking towards Iranian (national) experts without any reasonable evidence
B9	Adherence to anti-value	A tendency to legal abuse and cheat as a value, having a system based on relationships, prior personal interests over public ones because cheating is a cultural value and is equal to cleverness
B10	Deep gaps	Deep gap in cultural, social, and characteristic between stakeholders

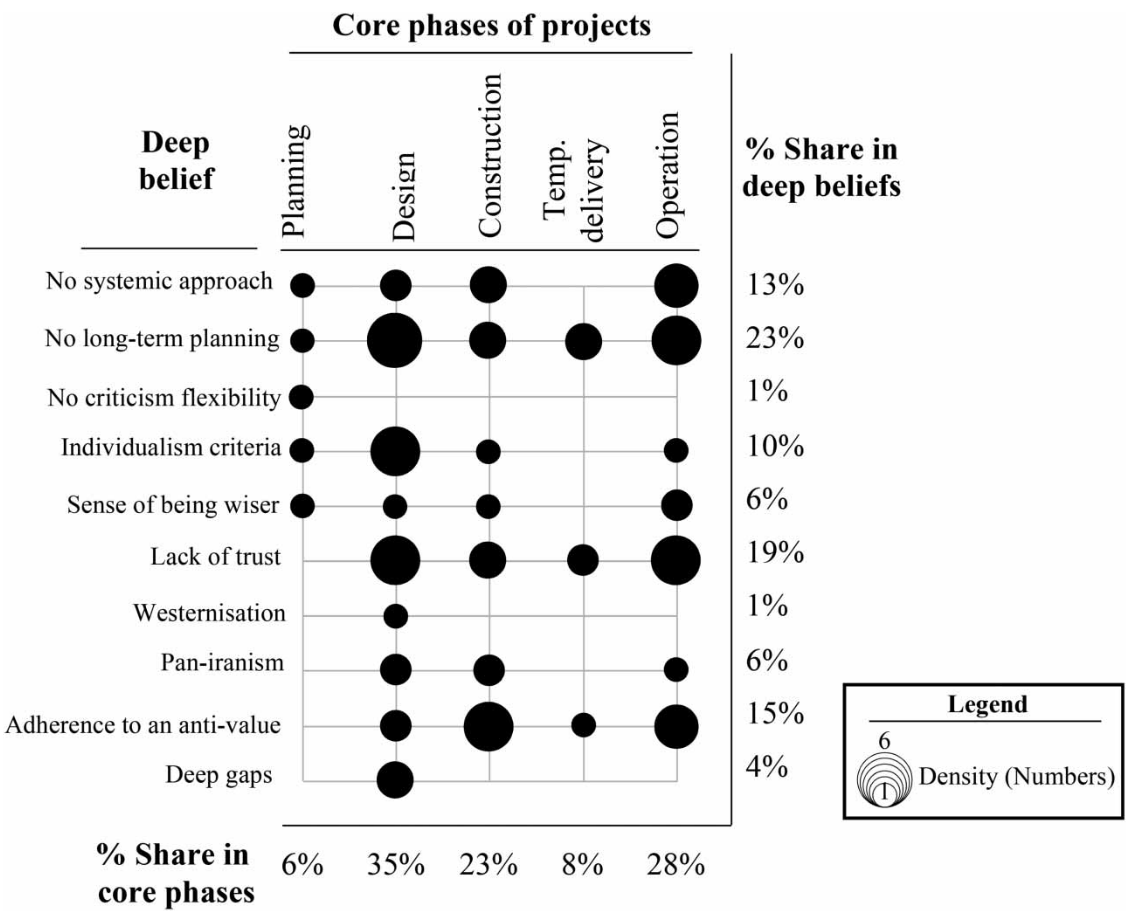


Fig. 8 | Distribution of deep beliefs within the core phases of the projects.

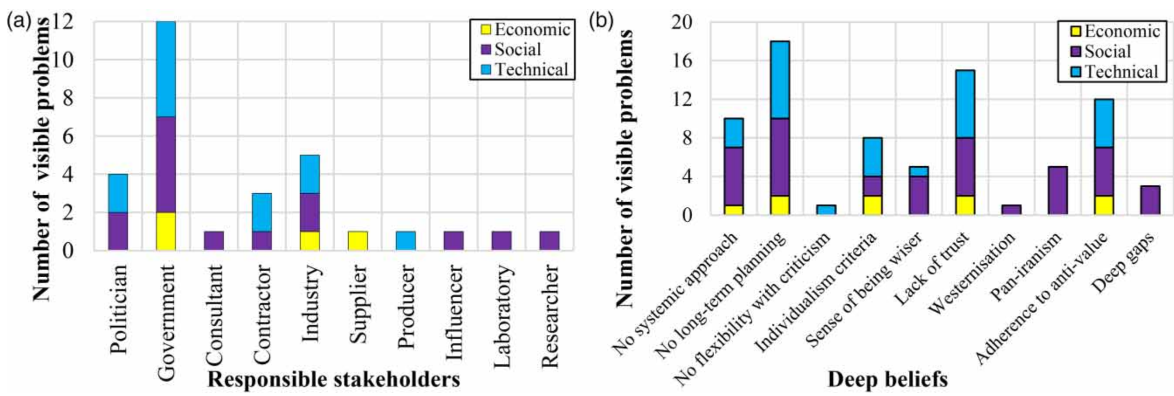


Fig. 9 | Distribution of identified visible problems based on (a) responsible stakeholders and (b) deep beliefs.

are categorised as responsible stakeholders causing social problems only. While each type of visible problems needs a unique solution, economic problems can be resolved by the same method applied for many responsible stakeholders. However, records for the number of visible problems show the government is responsible for several problems compared to other stakeholders. This implies that until these problems are not addressed, ATU development is unlikely to be on the right track.

The key massage of comparison between visible problems and deep beliefs of stakeholders is to understand how to translate beliefs into visible problems. This is crucial as these beliefs are usually hidden behind the visible problems and original and true instincts are hard to be recognised. For example, while running ATU projects needs at least 3 years (Figure 5), managers prefer to agree with developing projects with the shorter required time to account these projects operational as an outcome of their management period. Consequently, insufficient budget is always reflected as the main issue unless associated deep beliefs are properly understood.

Figure 9(b) shows the distribution of identified deep beliefs in the forms of economic, social, and technical visible problems. As can be seen, 4 out of 10 identified deep beliefs are reported in all three forms of visible problems likely due to the complexity of their situation that may not be understandable within one single form. These beliefs include ‘lack of systematic and long-term planning’, ‘lack of trust between different stakeholders’ and ‘adherence to anti-value action’. This deteriorates when the frequency of reported visible problems for these deep beliefs increases compared to others. Consequently, this situation clearly shows how deeper layers can change the understanding of visible problems with respect to complicated deep beliefs that may be difficult to resolve.

3.5. Deep mapping

Deep mapping aims to connect all vertical layers, i.e. visible problems, responsible stakeholders, and deep beliefs, to horizontal approaches, i.e. core phases of the ATU projects. Figure S2 in the online supplementary material illustrates full details of the complex network but part of it for the government is shown in Figure 10. These figures obviously implies that analysis of the ATU development can be an arduous task to understand when only visible problems are in place. Complex network between visible problems, responsible stakeholders, and their beliefs represents complicated transformation from visible problems such as economic or technical to deeper concepts including lack of systemic approach and long-term planning. More specifically, the frequency of lines in the earlier phases, drawn in Figure 10, shows the role of the government as main responsible stakeholders. However, their beliefs and consequent actions cannot be translated easily into uniform type such as just economic or social form and require further deep analysis. While some social visible problems can be connected to deep beliefs, finding relationship between deep beliefs and technical problems, for instance, seems to be impossible. Hence, this mapping can reveal the complexity level of problems in the ATU development and provides at least a network that connects different layers to each other which can be used for further long-term planning and management.

3.6. Limitations

The present study had the following limitations: (1) it highly relied on expert judgments, especially for finding visible problems. This is mainly because the case study suffers from proper historical experimental and numerical data, (2) while all stakeholders involved in the questionnaires were already verified, the number of experts and specialists in the industrial wastewater recycling projects of the case study are limited because these projects were developed recently, and (3) while the study aimed to reduce or remove the effect of conflicts between

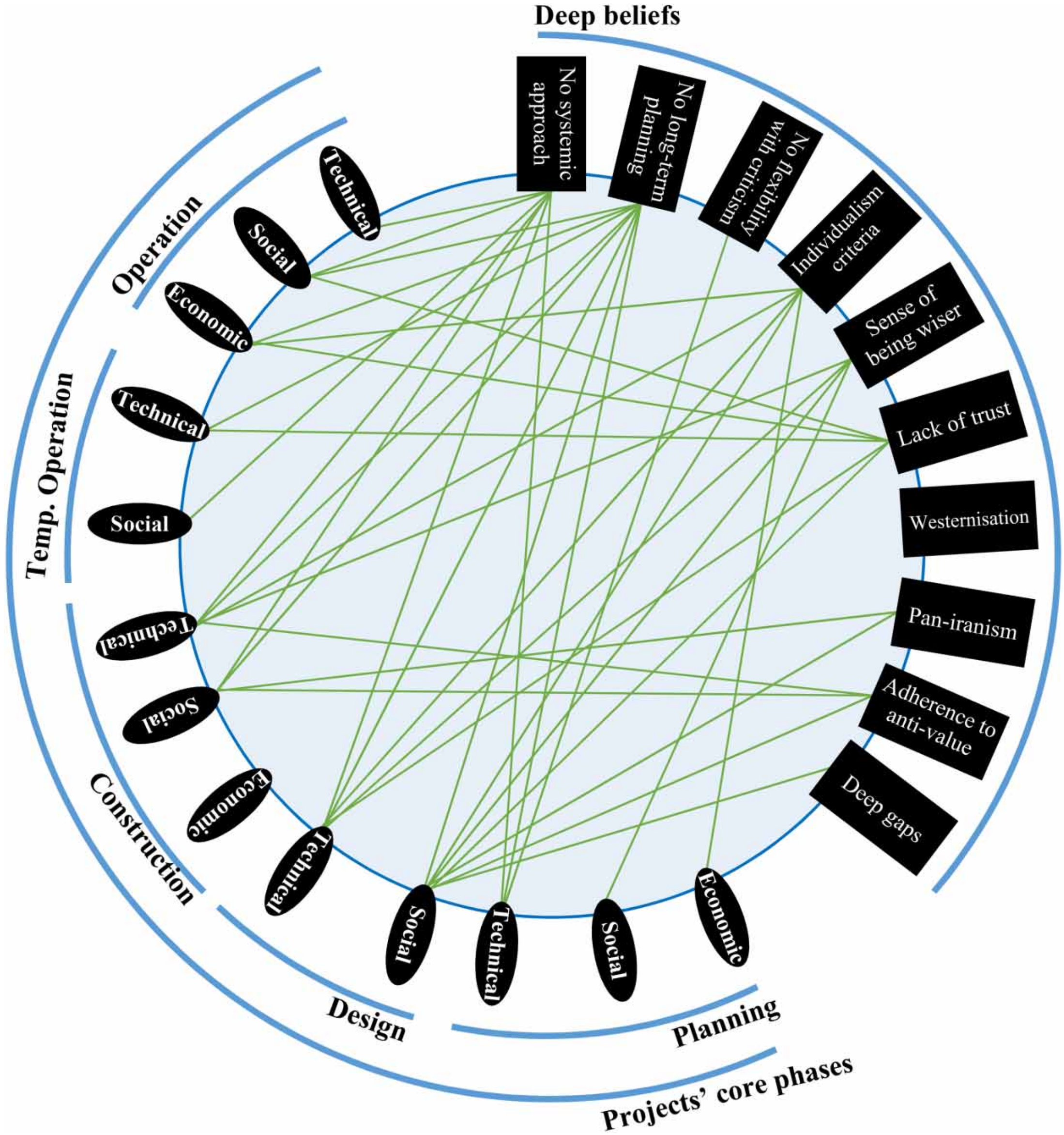


Fig. 10 | Deep network mapping between identified visible problems for the government, and their beliefs through the core phases of ATU projects.

stakeholders, this issue is inevitable and hence identifying the opposing and contradictory opinions raised from this issue was difficult.

4. CONCLUSIONS

This paper presented a new decision-making framework to identify visible problems, relevant responsible stakeholders, and the role of their beliefs in the core phases of industrial wastewater reuse projects (i.e. planning, design, construction, and operation) by using both qualitative and quantitative analysis, including stakeholder analysis, CLA, deep mapping, and frequency analysis. The methodology was demonstrated by its application to a real case study in industrial parks in Iran. Based on the results obtained, the following can be noted from this study:

- To prioritise the importance of distinct phases of ATU projects, frequency of visible problems per se cannot be considered but timeframe for occurrence of these problems is also important. For example, planning and design phases usually take less time compared to construction and operation phases and any delays in these phases caused by any visible problems can effect more than other phases.
- By connecting the role of responsible stakeholders to visible problems, it can be seen that some stakeholders are responsible for some problems that have no official role. This implies that those problems cannot be addressed through administrative procedures and consequently those with no official role may have to take their own method without accepting their roles.
- Identifying deep beliefs can reveal that most of the deep beliefs are hidden behind the visible problems and consequently original failure causes may never be recognised if these deep beliefs are unidentified properly. Hence, addressing the visible problems is insufficient to satisfy the needs for identifying deep beliefs and even if the problems can be resolved in short-time, but remain unresolved for longer periods.
- The deep mapping implies that the ATU development is a challenging task when only visible problems are considered and reveals the complexity level of problems in the ATU development. Deep roots are connecting complexly to visible problems across the project core phases. Hence, these beliefs and consequently associated actions can be challenging to understand and resolve.

It seems this study gives opportunities to interested stakeholders to extract and remove the obstacles depending on how they want to face the issue. In other words, while detailed visible problems may be easily handled in these projects, they may be presented again in short-term or in further projects because their roots are not actually realised. However, beliefs can alleviate the problems over a long-time period but require more budget, significant time and agreement between a wide range of stakeholders. Therefore, integrated and comprehensive assessments are suggested for each strategy in future research works. This assessment can aid to clarify the best option, requiring less financial budget, more willingness for stakeholders to accept and less time duration to plan and operate those strategies that are crucial to make informed decisions by stakeholders.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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