Identification and classification of construction delay causes in the wastewater treatment projects

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Abstract: Delay in completion deteriorates the national capital. In the last decade, few studies have analysed the delay causes in construction of wastewater treatment plants (WWTO). This study identifies and classifies construction delay causes in Iranian WWTP. First, using the SLR method, construction delay causes are collected and after conducting descriptive analysis, eight main delay causes are identified. Kappa index is used to measure reliability of proposed model. Then, using the survey method through conducting semi-structured interviews and TDA of the content of interviews and assessing content validity and components of interviews with indices CVR and CVI, six main themes of management, manpower and logistic, methodology, engineering and execution, errors and rework, and external factors are classified as the most significant construction delay causes. These themes can be used in risk management to prevent delays, optimise use of financial resources, manage effectively, make better decisions and prevent waste of national capital.

Keywords: delay causes; facility infrastructure; wastewater treatment projects; systematic literature review; SLR; thematic data analysis; TDA.

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1 Introduction

According to existing studies, construction industry is one of the main industries in the world, contributing to most of a country's GDP (Khan, 2015; Zarei et al., 2017) and according to the World Bank, share of the construction industry in developing countries is about 6 to 9% of the GPD (Kabirifar and Mojtahedi, 2019). In most countries, this sector is considered as the largest industrial employer and includes about 7% of total employment worldwide (Horta et al., 2013). According to the Statista Report (Global construction Costs 2014–2025), total construction costs is expected to reach $ 14 trillion in 2025 (Hossain et al., 2019).

On the other hand, with the growing population and the increasing trend of industrialisation, the need for housing construction, developing national infrastructure and public services has increased (Weber et al., 2016) and environmental problems, particularly water pollution, are becoming increasingly serious. The impact of this issue is reflected in the imposition of double pressure on the construction or development of water and wastewater projects such as wastewater treatment plants (Wang et al., 2016). According to the latest report published by the Statistics and Information Technology Office of the Deputy Minister of Planning of the Ministry of Energy of Iran in 2019, about 52.4% of Iran's population is covered by the services of wastewater collection networks. On the other hand, the sixth development plan of the country aims to increase the population covered by wastewater collection and wastewater treatment facilities to 72% (Ministry of Energy, 2019).

However, the increasing complexity of the construction industry projects has made it difficult to predict some important performance indicators and measure success and satisfaction, such as project scheduling accurately (Borges et al., 2018). Therefore, delays in long-term projects that increase costs, quality problems, and even safety (Venkatesh and Venkatesan, 2017), are considered as one of the main concerns of project managers and play a key role in judging the performance in terms of project success or weakness (Khan and Gul, 2017). Attempts to reduce the risk of delays have not been successful enough due to the complexities involved in standardising construction projects. The first step in avoiding delays involves identifying potential underlying causes that may vary in each region (Tafazzoli and Shrestha, 2017).

There are many studies about the causes of delay in various construction or infrastructure projects, but there are a few studies on facility infrastructure projects in Iran. Therefore, this study aims to identify and classify construction delay causes in wastewater treatment projects as a kind of complex and multi facility projects, which may lead to better time management in these projects specially in COVID-19 pandemic.

2 Literature review

Since this study is focused on identifying and classifying delay causes in wastewater treatment projects, the literature review section is divided into two sections. At first, the issue of delays in facility infrastructure projects is assessed, and then, an overview of wastewater treatment projects and the need to investigate the delay causes of such projects are addressed.

2.1 Delays in infrastructure projects

The main challenge of infrastructure projects is working in nature and the most difficult type of these projects are those that need excavation. Because it is not possible to see clearly what is happening deep below the surface. Sometimes, unfavourable geological conditions while implementing the project cause project delays and extra cost (Frimpong et al., 2003). Therefore, in infrastructure projects, contractors are often asked to identify risk factors for each challenge or uncertainties in the projects, to estimate the probability of their occurrence and their impact on the project, and to develop plans and strategies to reduce or resolve the project problems (Fallahnejad, 2013; Feyzbakhsh et al., 2017). Delays can simply lead to disruptions in the process and loss of productivity, conflicts, loss of contractor reputation, loss of opportunity to implement future projects, loss or reduction of profit margins, bankruptcy of the organisation, late completion of the project, increased costs, and even contract termination (Chaphalkar and Iyer, 2014; Frimpong et al., 2003). Therefore, it is necessary to identify and classify delay causes to help the project management team achieve the determined goals and avoid delays (Alshibani and Alhajri, 2018).

Common delay causes are divided into two categories of controllable (technical) and uncontrollable causes. Controllable causes refer to predictable causes such as improper scheduling, and technical mistakes in the design or construction phases, which reduce project productivity (Ahmed et al., 2002). Uncontrollable causes refer to the causes that are not under the control of stakeholders. These causes are mostly related to external conditions of the project or climatic factors (Love et al., 2010). Thus, it is very important to identify technical and controllable causes to prevent and reduce unnecessary reworks in the project.

2.2 Wastewater treatment projects

Wastewater treatment is considered as a complex project by Santana (1990). However, Cheng et al. (2016) classify wastewater treatment projects as economic infrastructure projects. Wastewater distribution and collection network projects and their construction often face unknown incidents due to the complex nature of facilities in both underground and surface operations.

Issues such as locating the existing assets, underground conditions, uncertainty of soil type, collision with other infrastructure, mutual influences between pipes and soil, problems related to the right of way (ROW), design and construction of entry, exit, and wastewater channels, pipe manufacturing materials, etc. are among the challenges facing such projects (Vijayeta et al., 2018). These unwanted variables, in addition to causing delays and extra costs in the project, result in dissatisfaction and conflicts of stakeholders including the employer, consultants, and main or sub-contractors (Fallahnejad, 2013; Doody and Bailey, 2016).

2.3 Research gap

One of the priorities of Iran in infrastructure projects is applying passive defense considerations, and wastewater treatment projects are considered as a subset of infrastructure projects in national civil projects (Ministry of Energy, 2019). Due to the issue of water crisis in Iran, the need for refining and reuse of sewage is very necessary and important. Most of these projects in Iran are financed by government (Samarghandi et al., 2016), so implanting such projects without considering delay causes will waste national funds and result in dissatisfaction of key stakeholders and the society.

In addition, delays in the implementation and exploitation of these projects leads to increases the pollution of groundwater (Tajrishy, 2010) especially in industrial cities (Piadeh et al., 2014), followed by creating a crisis in the environment and compromising health and public health which is in contradiction with the 6th goal of UNESCO 2030 document in order to ensures the availability and management of stable water and sewage for all (United Nations, 2017). Consequently, identifying the construction delay causes by reviewing the existing studies, and applying subject matter experts (SMEs) experience in this field play a key role in managing risks related to delays to pay special attention to optimal management of these projects during the project lifecycle specially in COVID-19 pandemic. So the purpose of this research is to answer the question ‘what is the most important causes for delay in wastewater treatment projects in Iran’, as a complex and multi-facility project, especially during the COVID-19 pandemic period.

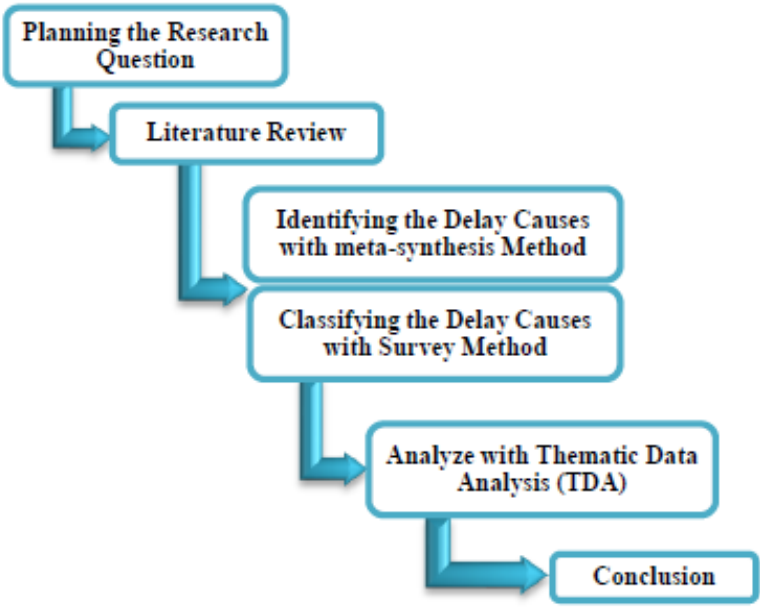
3 Methodology

Methodology is a way to solve the research problem regularly, and should examine and analyse critically the ways of matching the theory. Using an appropriate methodology can have a significant impact on the obtained results (Okoli and Schabram, 2012). In order to achieve the goals of this research, a qualitative research approach has been adopted and its methodology includes two separate parts:

- Part (1) is identifying the delay causes in wastewater treatment plants using the systematic literature review (SLR) method, in which the researcher aims to achieve the goals determined in these steps by collecting existing references.
- Part (2) is classifying the delay causes in wastewater treatment plants using survey method through conducting semi-structured interviews with experts active in the field of treatment plants, in which the researcher classifies the most important causes with the aim of understanding the experiences of others and understanding the

meaning of that experience. A summary of the implementation steps in this research is illustrated in Figure 1

Figure 1 Main steps of research implementation (see online version for colours)



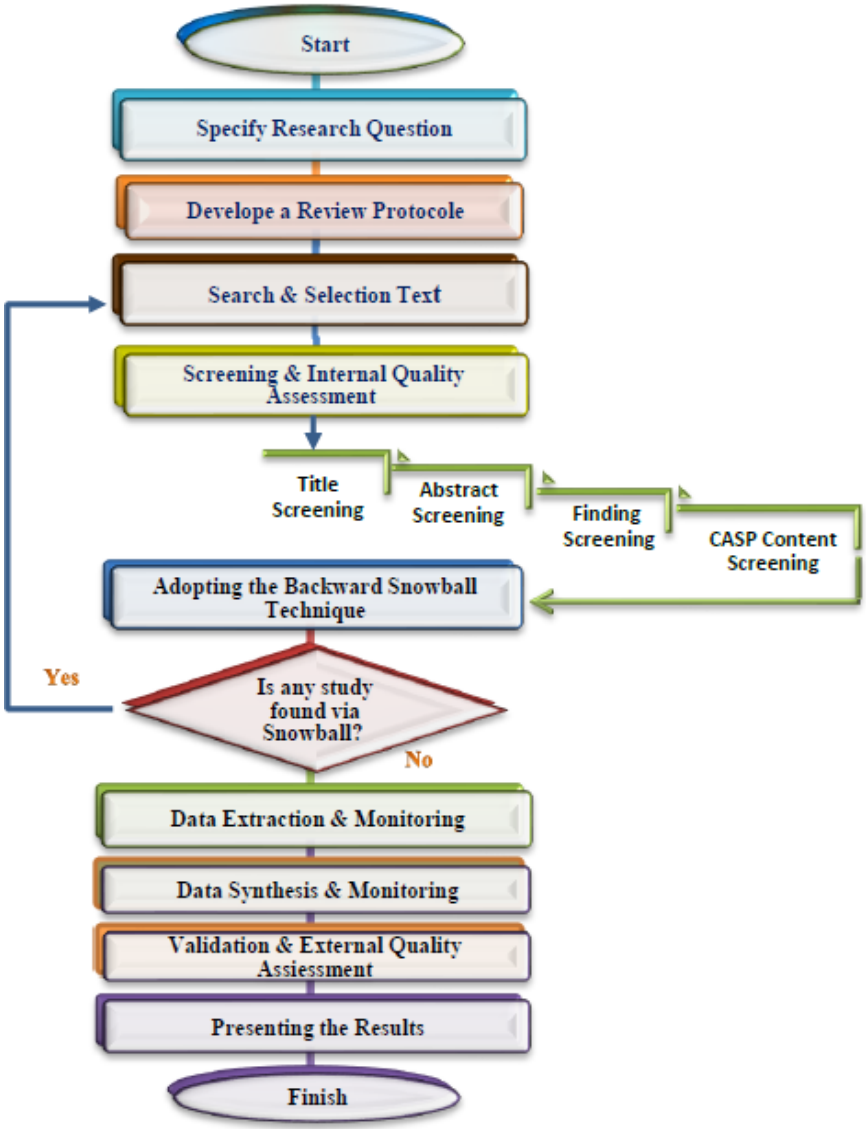
3.1 Systematic literature review (SLR) method to identify delay causes

The SLR method has been used to answer the objective of identifying delay causes in the construction phase of facility infrastructure projects. Today, in information bombardment and the richness of scientific resources, the methods used to review resources are traditional methods and lack a certain standard, and are often limited to well-known articles, in which the researcher states a summary of each topic without a certain strategy (Knoll et al., 2018). Generally, there are two types of review articles: narrative review and systematic review. When little evidence is available, narrative review is valuable. Since individual studies highlight just one aspect of research (Silva, 2015), the author's personal beliefs may influence the obtained results (Mulrow, 1987).

When a literature review is performed using a systematic and accurate standard, it is called the SLR (Silva, 2015). In fact, SLR is a kind of review that it's obvious difference with the common method of literature review is in the degree of the accuracy of the researcher and the better quality of obtained results (Okoli and Schabram, 2012). Since causes, impacts, and range of delays in the construction industry vary from one country to the other due to environmental, topographical, and technological limitations (Love and Sohal, 2003; Isasare and Bhirud, 2018) so in selecting the references to answer the question, it is attempted that the reviewed articles include all geographical regions, and to minimise the researcher judgment in selecting articles, in order to identify the initial data of delay causes with better accuracy. According to the flowchart presented in Figure 2 for implementing various stages of SLR, the first step in SLR studies is to ask clear questions

in order to achieve the goals that have a significant impact on the research success (Doody and Bailey, 2016).

Figure 2 Macro procedure of the SLR methodology (see online version for colours)



The next step is developing an appropriate protocol that according to Brereton et al. (2007), a protocol should be developed before conducting a systematic study to ensure the review accuracy. All of the selected articles are screened at several stages to select the best ones (Okoli and Schabram, 2012). The CASP checklist was also used in screening and selecting the articles of this study. The CASP checklist is the most commonly used critical evaluation tool for critical review of qualitative studies. It is designed by The Journal of the American Medical Association (JAMA) on 1994 (Heydari et al., 2017).

It examines features such as research goal, methodology quality, research plan and strategy, data collection method, reflectivity (methods of communication between researchers and subjects), ethical principles in research, study analysis, research achievements and findings, and the value of a qualitative study. And finally, interpretation of findings which is also called the synthesis of results, and is the analysis of findings obtained from implementing the previous steps and includes a combination of facts extracted from using appropriate quantitative or qualitative techniques (Okoli and Schabram, 2012).

3.2 Survey method to classify delay causes

The survey method has been used in this research to classify the most important delay causes in the construction phase of wastewater treatment projects. Survey study is a quantitative method that requires standard information about the topics under study, and its subjects can be from different individuals, groups, and organisations (Zidane et al., 2015). Interviews and questionnaires are one of the methods of surveying people and collecting data in survey studies. In the interview as a qualitative study, the sample size is limited by the time available for data collection (Baker and Edwards, 2012).

There is no rule for determining the appropriate sample size. Therefore, a general criterion is needed to estimate the saturation point. Kuzel (1992) suggests 6–8 interviews for a homogenous sample and 12–20 data sources to search unconfirmed evidence or try to achieve 'maximum diversity' (Guest et al., 2006). According to the Baker and Edwards (2012) suggestion on saturation requirements, the participants of the study should have appropriate experience about the topic of research. After selecting the sample, in order to prevent potential information gap at the end of interviews, the interview protocol framework was first examined based on the matrix proposed by Castillo Montoya (2016).

The interview protocol refinement (IPR) framework is suitable for refining semi-structured and structured interviews; and qualitative researchers can improve the quality of interview data through IPR (Castillo-Montoya, 2016). There are two types of review: descriptive study and analytical study. Descriptive survey refers to identifying and counting the frequency of a certain response among the study group. Analytical studies refer to the analysis of the relationship between different variables in a sample group (Zidane and Andersen, 2018). In this study, thematic data analysis (TDA) (Braun and Clarke, 2006) was used to identify, analyse, and report the themes and subthemes in four datasets. Thematic analysis is a qualitative approach that examines research data to understand and demonstrate people's experiences when encountering, interacting, and living with those experiences (Braun and Clarke, 2006).

4 Data analysis

As mentioned above, the methodology of this research is performed in two parts, each of which includes specified subsets. The steps determined at the first stage are based on the eight steps presented in Figure 2 part two includes conducting interview and collecting data, TDA and finally presenting findings. These parts are as follows:

4.1 Systematic literature review (SLR) analysis

SLR is a systematic way to identify, select, and critically evaluate all relevant studies, as well as collecting and analysing the data obtained from existing studies based on regular and pre-determined steps. These steps are:

4.1.1 Specify research questions

To begin, an important research question should be asked. Accordingly, this research question is: What are the most important delay causes in the construction phase of facility infrastructure projects?

4.1.2 Develop a protocol

The second step of SLR is protocol development. In fact, a protocol is like a researcher's roadmap that describes the behaviour of a systematic review of systematic studies and determines the details of the steps of systematic review. In developing the protocol, it is necessary to determine acceptance/non-acceptance criteria and keywords.

- Inclusion and exclusion criteria
- Language of articles: English
- Release time: 2000 to 2020
- Research methodology of articles: qualitative, quantitative, or combined
- Type of studies: the articles published in reputable scientific journals with a quality degree of Q1 to Q3 and scientific conference papers with SJR index
- Scope of study: facility infrastructure projects including, water and wastewater, oil and gas, tunnel, subway, railroad, rail lines, and transmission lines. Determine keywords: The keywords of this study searched in databases are based on Boolean logic as follows:

4.1.3 Search and selection of texts

After selecting the appropriate keywords, the researcher should select the appropriate scientific databases to search and collect evidence. Thus, the list of databases used in this study was determined based on the (Table 2) 293 articles from the searched databases were studied as relevant and appropriate sources for the subject and goals of the research.

4.1.4 Screening and quality assessment

As the number of studies conducted in databases is very large, in order to avoid confusion and to improve the quality of selecting reference articles, it is necessary to perform several screening and quality evaluation. In this study, critical appraisal skills program (CASP) checklist was used after screening the title, abstract, content, and findings of articles. According to the Likert scale (0–5), the score of each criterion is different. Finally, the total scores of each article were evaluated based on the Rubric scoring system, as excellent (41–50), very good (31–40), good (21–30), medium (11–20), and poor (0–10). The articles that score below 'very good' were removed from the review

process. The flowchart of the screening process to achieve the answer to the first question is presented in Figure 2.

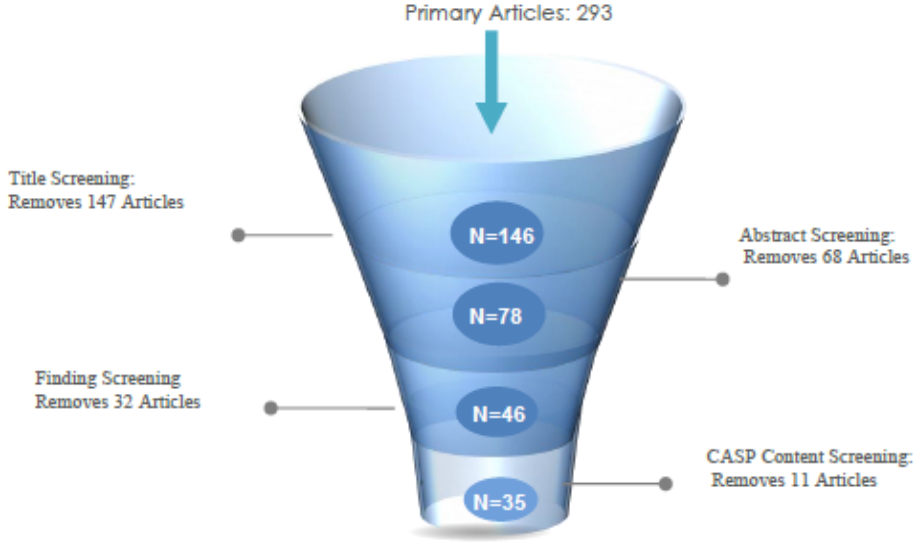
Table 1 Determine the keywords

Specify keywords		
	Boolem	*Keywords*
Inclusion keywords	AND	'Cause of delay' OR 'delay causes' OR 'causing delays' OR 'delay factor' OR 'schedule delays' OR 'time overrun' OR 'time extension'
		'Construction phase 'OR 'executing phase' OR 'implementation phase
	AND	'Infrastructure' OR 'infrastructure facility'
Exclusion keywords	NOT	'Highway' – 'road'

Table 2 Secondary search results articles

Publisher	*Google scholar*	*Emerald*	*Taylor & Francis*	*Science direct (Elsevier)*	*Springer link*	*Total*
Number of potential studies	84	44	24	78	63	293

Figure 3 Articles screening and removal process (see online version for colours)



As presented in Figure 3, in the first screening step, those article titles not related to the research question were removed from the 293 selected articles (147 articles were removed and 146 articles remained). In the second step of screening, the abstract of the remaining articles from the previous step were completely reviewed and those articles that their abstracts are not agreed with the research were removed (68 articles were removed and 78 articles remained).

Qualitative results and findings of the remaining articles were reviewed and those articles that did not have new findings or duplicated the results of previous studies were removed (32 articles were removed and 46 articles remained). In the fourth step of screening, the content of the remaining articles was studied more seriously and critically, and those articles that did not gain the required qualitative score (very good) by the CASP evaluation method, were removed (11 articles were removed and 35 articles remained). Therefore, the sample size of 35 articles was selected for the next step.

4.1.5 Data extraction

After screening and selection of final articles, the applied information of each article was extracted and coded systematically using the QSR Nvivo software, in order to categorise the raw data collected based on its significance. Initially, the articles selected from the previous step are uploaded in the software environment (35 sources). Then, all causes extracted from the articles selected from the first step of coding are released (630 nodes). Considering the similar concept of each code, axial categorisation is performed (203 categories). The codes that have overlap with each other are specified to resolve the overlaps and are considered as one code (27 codes). The codes with common content are also determined, and one common code is assigned to them (88 contents).

4.1.6 Data synthesis, monitoring and presenting the results

Interpretation of findings, which is also known as the synthesis stage of results, categorises the concepts in 31 subgroups, and finally these groups are classified into 8 groups based on their similarity. These eight groups are considered as the main delay causes.

4.1.7 Validation and external quality assessment

Findings validation in this study was examined through calculating the Kappa coefficient for quality control of codes and concepts and investigating the agreement score between the experts. Therefore, in a focus session, the other three experts were asked to reclassify the codes. 16 main groups were created by the researcher in four categories. The judges created 12 groups in four categories, which 12 common categories and one uncommon category were determined. Therefore, the kappa coefficient was 0.639, which according to the Cohen's kappa coefficient classification, this number was at the range of valid agreement. Thus, classifications and findings of the researcher can be published.

4.2 Semi-structured interview analysis

In order to localise the presented classifications for water and wastewater projects in Iran, the research team interviewed experts in the field of wastewater treatment project. The sample selected based on quota sampling includes three representatives of the employer, three engineering managers from the contractors group, and six subjects from the consultants group in two subgroups of monitoring and design, i.e., three experts from the monitoring group and three designers from the consulting design group. The criteria for selecting the interviewees were:

a experts with more than five years professional experience

b experts with a history of presence and activity in facility infrastructure projects focused on the wastewater treatment sector.

Both criteria were important, because the provided insights increase the validity of the data. The distribution characteristics of the statistical sample of experts are presented in Table 3.

Table 3 Background of interviewees

No.	*Code*	*Experience (years)*	*Gender*	*Type of organisation*	*Position in the professional body*	*Education*	*Discipline*	*Mode of interview*
1	CL1	14	Male	Owner	Expert	MA	Mechanic	Face to face
2	CL2	22	Male	Owner	Expert	BS	Civil	Face to face
3	CL3	11	Female	Owner	Expert	MA	Civil	Face to face
4	CONS1	17	Male	Consultant	Project manager	BS	Electrical	Face to face
5	CONS2	18	Male	Consultant	Director of Geo technics	BS	Civil	Face to face
6	CONS3	17	Male	Consultant	Legal and contracts manager	BS	Civil	Face to face
7	CONT1	11	Male	Contactor	Engineering director	PhD	Civil	Face to face
8	CONT2	20	Male	Contactor	Engineering director	PhD	Civil	Skype
9	CONT3	26	Male	Contactor	Engineering director	BS	Civil	Skype
10	DES1	17	Male	Designer	Design manager	MA	Architecture	Face to face
11	DES2	8	Male	Designer	Designer	BS	Civil	Face to face
12	DES3	7	Male	Designer	Designer	MA	Architecture	Face to face

A significant portion of the selected sample (50%) had a bachelor's degree, and 33% had a master's degree. Moreover, 33% of participants (15–20 and 25%) had 10–15 years' work experience in the field of infrastructure projects. This statistic shows the participation of a very experienced and knowledgeable group. The reason for collecting this data is ensuring that the respondents had the minimum pre-requisites for significant participation in the research, and their knowledgeable opinions and feedback contributed

to the researcher's decision-making process to analyse the findings and to present the results.

Table 4 CVR and CIR Ratio by themes and subthemes

Theme	*Subtheme*	*CVR*	*CVI*
Management theme	Financing problems	1.00	1.00
	Poor communication	1.00	1.00
	Contractual issues	1.00	1.00
	Delay decision making	1.00	1.00
	Incompetence and low experience	1.00	0.83
Error of design theme	Poor constructability	1.00	1.00
	Inadequate details	1.00	1.00
	Rework/mistake	1.00	1.00
	Change orders	1.00	1.00
Executing/engineering theme	Poor site management	1.00	1.00
	Weak planning and scheduling	1.00	1.00
	Poor risk allocation and HSE problems	1.00	1.00
	Technical and executive weakness of the contractor	1.00	1.00
	Poor monitoring and inspection problems	1.00	1.00
Resource and logistic management theme	Low productivity and performance problems	1.00	0.83
	Shortage of technical labours	1.00	1.00
	Equipment problems	1.00	1.00
	Lack of competent supplier	1.00	0.83
	Non-adherence of material specifications	1.00	0.83
	Late delivery of materials	1.00	1.00
	Shortage materials	1.00	1.00
Methodology and information flow theme	Inappropriate construction methods	1.00	0.83
	Poor administrative and information flow	1.00	1.00
	Incomplete documentation	1.00	1.00
	Bureaucracy problems	1.00	1.00
External causes theme	Weather condition	1.00	1.00
	Environmental, social and culture issues	1.00	0.83
	Economic crisis and political situation	1.00	1.00
	Acts of God	1.00	1.00

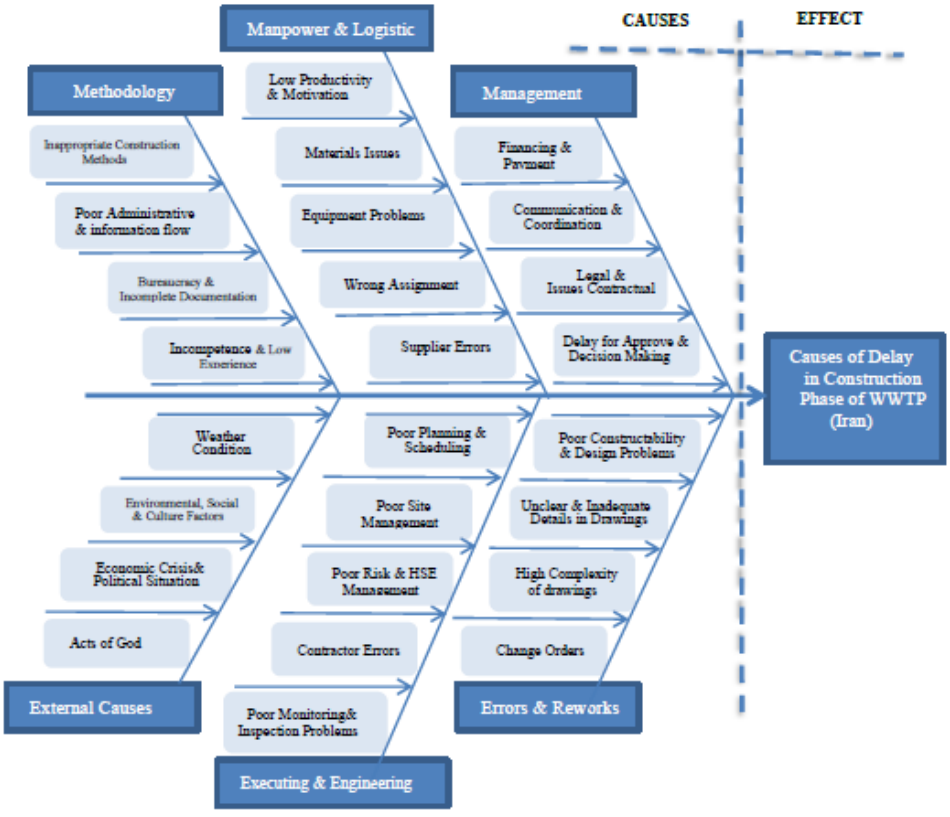
4.2.1 Conduct interview and collect data

In this study, nine interviews were conducted in face-to-face manner, and three other interviews were conducted through Skype because of far distance and the beginning of COVID-19 pandemic. In all interviews, with the coordination and agreement of experts, their voices were recorded to prevent note-taking errors due to the limited interview time (45 to 60 min). After conducting 12 interviews, the data reached theoretical saturation

and the interviews were stopped. Then, a copy of the interview text was sent to the experts, so that the interviewees' opinion on whether they agree with the interviewer's ideas for interpreting the answers could be asked, in addition to providing the opportunity to present and complete the interviewees' answers.

According to the TDA process, in the step 1, the researcher becomes familiar with the data and then the data is uploaded in the QSR Nvivo software to continue the coding process. In the step 2, 412 preliminary codes were systematically developed. And in step 3, the identified codes were classified and combined based on their conceptual similarity and 190 codes were organised in the form of possible themes and sub-categories. In step 4, 30 concepts were extracted through overlap in axial coding. Then, in step 5, based on all the sub-themes identified in the whole research, a more general classification was performed, which led to the identification of the main themes as delay causes in wastewater treatment plants.

Figure 4 Delay causes in WWTP. Iran (see online version for colours)



According to the findings of interviews, the presented model from the SLR studies was modified. These modifications were provided to six academics in order to scientifically confirm their content validity according to the degree of coordination between the content of the measurement tool and the final goal of the research. For this purpose, the content validity ratio (CVR) was used to examine the 'component validity', and the content validity index (CVI) was used to examine the 'criteria validity'. According to Lawshe

(1975), given the 'number of experts', a special number is defined for the minimum CVR, which is 0.99 for these 6 experts. In this research, the CVR index for model components was equal to one and the CVI amount was 0.97. According to Lawshe table, if the average score of CVI is higher than 0.79, the content validity of that scale is verified. Therefore, content validity of the research model was verified by experts.

In the last step, after confirming the validity of the content and criteria, the model is presented and modified to examine the most important delay causes in wastewater treatment plants in Iran considering the effect of the global crisis of pandemic COVID-19, which is presented in Table 3.

4.2.2 Thematic data analysis

The data obtained from the interviews were analysed thematically using the TDA approach. In this analysis, qualitative responses were coded using QSR Nvivo software. The results of the TDA of the interviews identified 6 themes as the main delay causes in the construction phase of wastewater treatment plants in Iran with some subthemes, including:

Theme 1: Management

All the experts consider the financial issues and late payments as the first delay cause in wastewater treatment projects. CONS (1) says: "Consultants and contractors measure the time on a financial scale and are willing to reduce costs and make a profit sooner by reducing time. However, if the financing is delayed by the employer, the contract type is not set correctly, or the early delivery bonus is not determined in the project, the contractor or consultant will have no incentive to continue the project with high productivity, and consequently they will work with lower productivity than their competence, and the project will be completed with high delays and low quality". Kim et al. (2016), Mahdi and Soliman (2018) and Wang and Lin (2018) also considered the payment problems associated with the owner's financial problems while Hammadi and Nawab (2016) and Wang and Lin (2018) believe the contractor's liquidity problems is more important. Of course, this issue is not irrelevant with sanctions and the economic problems of the society.

According to the consultants, communication is not just about management issues and influences whole of the project. Any neglect of communication issues can have the potential to stop the project process, such as slow decision-making. The effects of decision making also play a key role in all phases of the project. Like researchers such as Alshibani and Alhajri (2018) and Hossain et al. (2019), the SMEs believe slow decision-making and delay in approving and reviewing the statements by the contractor can have a significant impact on delayes.

The group of consultants and contractors think about improving decision-making, when in addition to appropriate communication, the parties involved in the decision-making process have access skills in using visual tools and data analysis to make decisions. CONS (3) stated that: "delay in decision-making has cost and destroys the contractor's motivation. Even sometimes, delay in decision-making eliminates the justification for the project. In addition, late payments, frequent change requests and lack of effective communication can increase the scope of project conflicts". All of SMEs agree with the direct and major impact of COVID-19 on the management theme because

it increases costs, a high delay in decision making, as well as reducing effective communication, especially in constraction environment.

Theme 2: Errors, rework and mistake

From the interviews analysis, it was found that according to the experts, design errors of wastewater treatment projects are divided into two main categories:

1 design/plan errors

2 specification errors.

In in-depth interviews, all experts consider rework as an important delay cause. 100% of experts agreed on the impact of engineering technical errors on delays that often lead to rework. They consider lack of constructability as one of their causes. The rework mentioned by experts can be analysed in two categories:

1 design rework

2 executive rework.

The experience of experts indicates that the contractor requests a change, which is because of the lack of analysis and the designer and the employer's thinking about feasible requirements. All experts believed that in the implementation phase, sometimes there are problems related to designs that were not implementable and represent lack of understanding of the designer about the details of construction or lack of constructability.

Another type of error may be related to the execution team. Although this factor is very important, despite the reports of other researchers, such as Hossain et al. (2019) who consider this factor as a high-ranking factor in the occurrence of delays, the results of interviews in this study show a lower share of latency in design and implementation errors. From the SMEs view of point; due to the change of the design and engineering companies' approach and their desire in the use of new technologies such as building information modelling (BIM) allow projects to continue in a digital and virtual environment, prioritisation tasks with the minimum presence workforce to install in the site, due to the requirements of social distance during pandemic. Also due to the growth of skills and efficient management training for companies and workers, the effect of COVID-19 on this theme is not impressive.

Theme 3: Executing problems

In the results of all researchers, it has been emphasised on the role of poor planning and scheduling and poor site management on the occurrence of delay. Also, all the experts consider incorrect planning and scheduling as the delay cause. CONT (2) believes that the planner should be aware of the executive site: "In Kamalshahr wastewater treatment plant, due to the criticality of some resources or HSE issues, we had to stop some parallel activities and just focus on one activity.

Due to the lack of knowledge and understanding of the planner of the sequence of activities and spatial and temporal restrictions of machinery performance on parallel activities, we were always behind the schedule". The opinion of the consulting group was like the contractors and they acknowledged the need for proper timing in the project. CL (1) also considers the experience and knowledge of the planner important in proper

scheduling: “Experience is the basis of speeding up the work. The more professional and experienced the planner is, the more aware he/she is of the planning points and knows how the sequence of activities, the time required for each activity, and the required resources should be defined in the project. An experienced planner is aware of critical resources and activities. He/she monitors deviation alarms and provides workshops and foremen and subcontractors with the executive plan. We can trust the advice of an experienced planner during the construction or facing risk”.

HSE issues were also among the issues that 100% of experts believed that should be considered regarding delays in construction especially in COVID-19 pandemic. CONT (2) believes that safety issues should be considered from two aspects; provide work environment safety and labour’s safety. He referring to an example, says about this: “In Semnan wastewater treatment project, sometimes due to observing safety zones and preventing the fall of machines and observing a distance of at least 4 metres in the path of truck traffic around the pits, the work speed was lower than the plan and this was because of the lack of knowledge of the planner about the sequence of risky activities. Consultants’ representatives believe that any weakness and lack of experience in these two areas can lead to project delay.

Even before this pandemic, poor risk management and HSE consequences were challenging in parts of construction site. Otherwise, the issue of the prevalence of infectious disease, reduce the number of labours for illness or the requirements of health protocols in order to keep a safe workplace are in the HSE risks group, which have had a lower presence in previous research, but in the current research, they were more emphasised by all experts.

Other issues raised by CONT (1) and designers in this them were related to lack of accurate initial estimation of the cost of the project, failure or error in geotechnical studies and tests and subsequently changes in site conditions. Another issue that experts, particularly the contractors emphasise as executing problems are failure to resolve disputes (traffic, property, facilities, green space, natural resources…) at the appropriate time, i.e., before the project is delivered to the contractor, which leads to great wastes of time.

Theme 4: Resource and logistic management

Considering resource management and logistics, the role of materials supply is more important according to the experts, and 100% of them agree on its impact on delays. CONT (2) states: “Logistics productivity is especially important in Iranian projects. In some parts of the Semnan wastewater treatment plant project, such as its tanks, concreting should be performed on a slope and widely. This issue requires the use of high-quality materials with minimal waste and concreting intervals. In addition to timely supply of materials, it is very important to employ a skilled and experienced labour. Because the benefits of considering these two issues ‘employing skilled and experienced labour and using high quality materials’ particularly when the weather conditions change or concreting is done on a slope, are very useful for construction managers”.

CL (2) regarding logistics issue, considers three factors of financial credit cost, supplier competency, and incorrect estimations as effective factors that can cause logistics problems. CONT (2) while considering logistics effectiveness in delays, and like the employer refers to the issue of suppliers’ collusion, still he believes that financial issues and liquidity play a key role in the logistics issues.

CONS (2) also consider important the role of inflation and financial risks in supply chain planning: "A significant part of planning is related to the issue of logistics. In logistics, we face construction procurement and labour, and if the planner does not have the sufficient experience in logistics planning, we will face serious problems. However, the significant problem in our country is inflation and sanctions, which causes delays. Planners should consider the logistics risks in their planning and scheduling".

Theme 5: Methodology

100% of experts believe that weak information flow insufficient data collected during the study, design and construction phases, dispersion of data in the project, not using advanced software, lack of suitable databases for loading and integrating data, inconsistencies in the data produced in different versions and not updating the generated data have caused confusion and mistakes of users and even rework and a lot of damages and losses in the construction and operation phases. CONS (3) believes that lack of appropriate technical and supervisory database and lack of control of the monitoring system on technical, contract, and executive issues of the country about infrastructure projects, is a main problem that should be taken into account.

Also according to the experts, "lack of experience, skill, and competency of stakeholders" is one of the delay causes in wastewater treatment plants in Iran, This issue is also raised by researchers for example, (Mahdi and Soliman 2018) related to the owner and contractor, (Chen et al., 2017; Muneeswaran et al., 2018) considered it in the designer's team, while Fallahnejad (2013), Hossain et al. (2019), Sweis et al. (2018) and Samarghandi et al. (2016) believed Lack of experience/competence of the contractor is more important.

The group of contractors and consultants believe that after the financing issues, lack of knowledge, competency, and experience of the individuals working in a wastewater treatment project is the delay cause. The employer is responsible for ensuring the competency, ability to design, effective consulting or implementation of the project in contracts. In terms of CON (2), many companies did not have much experience from confronting and managing a global crisis such as COVID-19 that led to a closure of many projects. But a lesson learned is considered for future projects, because companies learned a new Virchual management in parts of the project.

Theme 6: External causes

All experts believe that the impact of external causes, such as climate, on the delays is very high. CONT (3) considers the impact of this factor on the geographical areas, where cold weather and the risk of weather factors influence the construction process, as a delay cause and stoppage of construction: "If we are behind the schedule and face bad weather conditions, such as excavation in rainy conditions, the situation is to the detriment of the contractor, even if the impact of these factors are considered by the planner, still the impact of this risk should be resolved through the strategy of reducing and transferring the risk, such as insurance".

Other factors such as economic and cultural problems and force majeure are items emphasised by experts and are considered as external causes of the project delay. CL (3) considers the impact of delay causes and economic conditions bilateral. When it is possible to take steps towards economic development and welfare of the society using

available resources and capital, it is very unfortunate if these resources are used in a way that does not lead to proper outcomes". CONS(1) also considers important the role of economic issues: "Hyperinflation and lack of financial resources for implementation, particularly in the field of materials, machinery rental and even payments, create difficult conditions for contractors and practitioners in the construction sector in each project and country".

5 Discussion

According to the interviews with experts, the most important cause was related to financing issues and challenges, liquidity problems, delay in payments of the main contractors and subcontractors, which can cancel the contract between the parties and also damage the project itself. It is better to provide liquidity as well as financial payments in a timely manner so that the completion of the project is not delayed. Secondly, the site management and the project site in the construction phase gained a high score both in the studies of the first stage and in the interviews with experts.

The location of the site of infrastructure projects with large excavation volumes on hard and rigid grounds, not only leads to space constraints, but also challenges the problems related to the approach, material transferring, and pollution control. These conditions are: the existence of land conflicts, surface and underground conditions of soil (soil and geology), hydraulic conditions in wastewater treatment projects, ground conditions and the problem of environmental pollutants, discrepancies/topographic changes of site after design, insufficient geotechnical study that cause problems in ground operations and delays.

Technical and executive problems, such as rework, during the construction, influence the project performance. In contrary to the design phase, in which the engineers and designers try to solve the problems by repeating the complex relations, this repetition in the construction phase has bad consequences, such as increased costs and delay. Lack of constructability and unawareness of designers about the challenges of the construction phase lead to design errors and need a time lag to correct the design. This time lag influences the construction process and causes waste of time during construction. A change order may force the stakeholders to make significant changes to the current project, which leads to time and cost changes in the project. Clash (technical, time, and spatial) and lack of managing it can lead to time lag in the project. Delay in inspection and quality control can lead to destruction or rework in construction, in addition to slowing the contractor's approval.

Lack of considering personnel safety and health issues causes accidents and loss of life or property of the project, and may also lead to site closure and project delay. The dynamic nature of the construction site leads to changes in the number of individuals working in it, and space occupancy because of the activity of machines on the site and even loading and unloading. Logistics management and planning the site layout throughout the construction phase ensure high productivity, optimisation of material flow, and effective use of expensive equipment on the site. Delays in materials supply and delivery, planning, materials procurement for efficient project delivery lack of planning and support of pure construction and excessive production of wastes cause a significant waste during the project implementation. Labour and human resources are an integral part of the construction phase and one of the main resources of the project, which

is considered from the planning stage and the compilation of resources in the schedule. Therefore, planning and scheduling, as one of the coordination tools of available resources such as labour machinery, and materials based on the defined time and costs, provide a more accurate evaluation of the progress of the current situation and faster identification of the project problems and preventing rework or changes, just how a poor planning and scheduling increase the risk of project delays. In addition, the findings of the interview show that productivity is a factor that has a measurement rate, and two factors of time and cost has a significant impact on it. Although some resources state that productivity has a direct relationship with labour, some of the selected resources have reported this factor separately.

Conflicts between the stakeholders have been emphasised in all studies. Lack of transparency of legal and contract issues and ignoring this factor lead to confusion and disagreement between parties and can result in waste of time and cost in the project. Most experts believe that poor coordination and non-participation of stakeholders in communication result in rework or changes that consequently lead to project delays. On the other hand, experts point to the decision-making mechanism of project stakeholders or approval of plans, contractor statement, or necessary agreements and permissions during construction, which in addition to causing delays in the project can result in dissatisfaction of the contractor.

The implicit point of experts to the impact of inefficient methodology and technologies on the regular implementation of the construction phase of infrastructure projects indicates that in selecting the contractors and consultants and designers of infrastructure projects, it is necessary that their engineering and technological power be considered more by the employer for better selection of the contract parties. Because the efficient use of technology in a safe workplace ensures transparency and success of a construction project.

Correct definition of information flow and preparation of documents of each project plays a key role in collecting tangible information and its maintenance and transmitting in any project management system. Moreover, establishing the right information flow between the stakeholders improves the project integration and prevents many rework in the project. Documentation can help better identification of rework and wastes of the project and prevents their recurrence.

Weather conditions have been stated in all researchers' studies as an important factor that has not been in the control of any of the stakeholders. Some studies have referred to rainy conditions and the consequences of high temperature and moisture as inhibitory factors in the time management of the implementation phase. The impact of political factors and force majeure, such as natural disasters wars, etc. has been reported by most of researchers in the Middle East. It is another significant delay cause, and even prevents project implementation, and its control or management is out of the control of the project stakeholders.

6 Conclusions

6.1 Research conclusions

In this study, a primary model of the most important delay causes in facility infrastructure projects was designed through systematic review and qualitative meta-synthesis. For this

purpose, 293 articles were reviewed and finally 35 articles with higher screening scores were selected as the sample of this study and the framework of 'delay causes in facility infrastructure projects' was presented. Then, through conducting interviews with experts in the field of wastewater treatment plant and judgment of academics and thematic analysis, 6 main themes and 26 sub-themes were determined as the most significant delay causes in the construction phase of wastewater treatment projects in Iran. None of the previous studies has used SLR and meta-synthesis methodology to extract the causes for these project and also did not considered the impact of critical conditions of the occurrence of a pandemic such as COVID-19.

The findings of these studies indicate that financial and technical issues are not the only delay causes, but ignorance of solving management issues and resources can also influence the project delay or its failure. Poor risk management, lack of attention to safety and HSE issues, lack of use of effective technology such as BIM to avoid some of the challenges of direct work at the site and administrative office at critical conditions can be delayed in any part of the project. Since the project manager or construction manager is directly involved in the different phases of the project, and is considered as the project leader in difficult and critical conditions, it is necessary to identify all issues that cause project success or failure, and should try to resolve them.

6.2 Research contribution

This study has significant implications for research and practice. Industry environment is the place for applying skills, expertise, experience, working views, value and mental system of people working in it, which are obtained through observation or imitation, cannot be stated, and are not stored in any database. In fact, in industry we are faced with a kind of personal knowledge called 'implicit knowledge'. The challenge of knowledge management is transforming the implicit knowledge into another form of knowledge called explicit knowledge (implicit-explicit), which is easy to understand and transfer to others.

One of the ways of turning the implicit knowledge into explicit knowledge is 'case study'. It is known as a communication channel between industry and academia, and provides students and professors the opportunity to meet, discuss, and interact with each other to find a better solution for a real project with a design, construction, or operator team with the knowledge of implementation. It adds a new knowledge to the knowledge repository by putting science and experience beside each other. On the other hand, the industry, using the results of academic studies from a scientific perspective, identifies and evaluates innovative opportunities and newer competitive advantages. Therefore, collaboration between industry and academic research on how water and wastewater companies can manage their lifecycle with minimum waste of time, cost, and even materials, while observing the sustainability and pure management principles to meet the 17 goals set in UNESCO's 2030 sustainable development (facilitates and accelerates awareness and decision making in projects in this area.

6.3 Recommendation

The SLR approach used in this study can be used to effectively review the existing literature in other areas of the project, in order to provide higher quality results. Discovering and understanding the challenges and thus identifying the capabilities and

optimal solutions to reduce time wastes in case studies such as water treatment plants (as a complex facility project in this field) can lead to institutionalisation of this technology in the beneficiary companies of water and wastewater group. On the other hand, with the global crisis of COVID-19 in the world, which had a major impact on project delays, it is suggested that the effect of using advanced technologies such as BIM and virtual management at infrastructure projects be further examined.

There are some limitations in this study. Although some indicators were used in the systematic and meta-synthesis method to control the quality, still it is possible that a wrong article has entered in or removed from the research.

7 Ethics

1 All of the articles judged at the first stage of this research have been selected and analysed in accordance with the defined protocols and without prejudice.

2 Written informed consent was obtained from all subjects and their privacy right was guaranteed.

3 There is no conflict of interest in this study.

Appendices/Supplementary materials are available on request by emailing the corresponding author.

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