Environmental and Climate Technologies
2022, vol. 26, no. 1, pp. 982–997
https://doi.org/10.2478/rtuect-2022-0074
https://content.sciendo.com

Implications of the FMEA Method in Evaluating Amirkabir Dam's Environmental Risk

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***Abstract* – There are various environmental risks in both the construction and operation phases of huge civil projects such as dam construction. As a result, it is critical to implement appropriate risk control and risk mitigation measures before the initiation of the activities posed by these schemes. The goal of this research is to identify and categorize the environmental risks posed by the Amirkabir Dam during its construction and operation phases. After identifying the risks, the risk factors were prioritized using the FMEA method, with the risks being ranked according to their severity, probability of occurrence, and ability to detect. The study's findings revealed that the highest risk in the dam construction stage is associated with road construction and vehicle exhaust gases (RPNs of 280 and 252, respectively), and the highest risk in the operation phase is associated with borrow area overuse (erosion and sediment downstream of the dam) (RPN of 280).**

***Keywords* – Amirkabir dam; environmental risk; FMEA method; risk priority number; severity**

1. INTRODUCTION

In developing countries like Iran, water demand is increasing due to the high rate of urbanization and the development of industries. On the other hand, as Iran is located in a warm and dry area, water supply used to be a great challenge ever. Dam construction is a traditional method for this type of demand and it has got various undesirable effects on the environment. Building projects have the greatest death rate among industrial activities in most parts of the world, such as Australia, Europe, and North America, with fatalities ranging from 3 to 14 per 100 000 employees [1]. Dam construction may have all the physical, biological, social, economic, political, and ecological consequences, all of which are crucial. Environmental risk assessment is a quantitative and qualitative analysis process of potential hazards in a project as well as the vulnerability or sensitivity of the surrounding environment [2]. By combining the various projected effects acting on each risk factor, from the hydrology of the input to the estimation of the flood wave's effects on the population and assets at risk, the overall effect can be evaluated. Dam owners and experts in dam safety will find this information helpful in making decisions [3].

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Environmental contamination is an unintentional and small consequence of different industrial activities that have made the environment more vulnerable [4]. Recognizing and evaluating environmental threats and hazards to determine the most critical ones is one of the most important phases in environmental risk management [5].

In general, the risk assessment problem can be viewed as a multi-criteria decision-making problem. Due to their strong ability to analyse and prioritize, some researchers have suggested that multi-criteria decision-making methods be utilized to solve these challenges [6]–[8]. FMEA (Failure Mode Effect Analysis) is a multi-criteria method that is becoming one of the most useful risk assessment tools in recent years. Despite certain criticisms, the FMEA approach has captured lots of attention and has become a popular risk assessment technique because of its ease of use and high visibility [9]. FMEA is a team-driven process for evaluating the security and dependability of goods, programs, procedures, and systems to define, identify and remove identified or possible faults, issues, and errors [10], [11]. Reference [12] employed the FMEA method for dam risk assessment, and as a consequence, they were able to determine the risk priority number, likely failure modes, failure causes, and effects. They also identified the safety requirements for the subject's means of transportation.

The results of reference [13] studied the efficiency of the EFMEA (Expanded Failure Mode Effect Analysis) method in assessing the environmental risks of the Jarreh dam in Ramhormoz and showed that the highest number of environmental risk priorities in the dam is related to erosion and sediment downstream and fluid leakage of flow pipelines both with 252 RPN and the lowest risk is related to eutrophication with risk priority number 48 % and 10 % of the risks were at a low level, 20 % of the risks were at a high level, and 70 % of the risks were at a medium level. Reference [14] assessed the environmental risk of Gotvand Dam in the operation phase using the combined method of preliminary hazard analysis and EFMEA technique in a study. This study showed that in the EFMEA technique water salinity due to salt dome and due to reservoir dewatering, erosion and sediment downstream of the dam due to supply of borrowing area and creating human effluent due to high-risk tourism activity and with priority risk numbers (RPN) 320, 288 and 256, respectively, were introduced as the first to third ranks and the lowest risk priority number related to creating a suitable environment for growth and insect reproduction (the possibility of reproduction of Anopheles) was introduced number of 90, due to dewatering of the dam reservoir and soil compaction due to agricultural development and heavy machinery traffic with a risk priority. Reference [15] utilized EFMEA and MCDM (multi-criteria decision making) in their case study and regarding the RPN, they revealed that the risk of water pollution under high, medium and low conditions was determined to be the most significant risk of dam construction, with weights of 1300, 1000, and 700 respectively. According to the severity, likelihood of occurrence, and degree of pollution, the environmental risks discovered during the follow-up phase were weighted using the entropy technique.

Generally, risk analysis has been acquiring popularity as a means to deal with the uncertainties related to the behaviour of civil structures like dams. Failure Mode and Effects Analysis (FMEA) is one of the accessible methodologies [16]. It allows demonstrating the relevant components that can be used in future advancements through more complicated approaches, such as Event Tree Analysis (ETA) or Fault Tree Analysis (FTA). The potential of this methodology in detecting the likely failure modes of all components of a storage dam (Amirkabir Dam) is demonstrated in a case study of a storage dam (Amirkabir Dam). FMEA is a logical framework that allows experts and engineers to use available knowledge and information to develop a systematic understanding of the system's risk sources. It is an inductive failure-based methodology. It takes a step-by-step method, starting with a fundamental cause or initiating event and progressing to the final effects [17].

Many researchers conduct their studies regarding dam risk assessment with different methods. For example, reference [18] utilized Water Quality Index Method (WQI) for water quality evaluations and revealed that several ions, such as Al, As, B, Ba, Co, F, Mn, Ni, Pb, Se, and Zn, were discovered to surpass the national regulatory standards' limit values. As a result, the WQI values of the water quality are poor (below 60), although the source is suitable for industrial and agricultural use. Moreover, he mentioned that oral consumption poses non-carcinogenic health concerns to both adults and children at “medium” and “high” levels. The Hazard Index values for the B, F, and Pb components are all more than 0.1 and this could result in a “low” risk of chronic illness for children by oral ingestion.

Other researchers adopted the Fuzzy Best-Worst Method (FBWM) and Z-number theory (Z-MOORA) and found that in comparison to other standard methods such as FMEA and fuzzy MOORA, the results show that failures are fully prioritized [6]. Reference [19] conducted the study with methods of water quality index (WQI) and Geographic information system (GIS) and showed that after rainfall, the groundwater level climbed from 15–25 feet near the dams to 8–14 feet away from the dams, with only a slight change in chemical and trace element concentrations. The WQI found that just 20 % of the water samples were of exceptional quality, 25 % were good, 15 % were poor, 15 % were very poor, and 25 % were unfit for human consumption. Groundwater contamination was also indicated by the spread of water-related diseases in the area. Overall, the water quality is poor to unfit for human consumption. Other methods are stochastic Simulation for Multi-Agent Construction. Project (SMACC) based on the MADS-MOSAR method and in the realism of the SMACC model, which allowed us to mimic a genuine building project quite efficiently, is one of the major elements of our methodology. Non-risk managers find it challenging to utilize this strategy and a preventive and protective strategy can be created; this will be converted into a list of technological safety barriers or applications that will neutralize these scenarios [20]. Reference [21] used the Fuzzy Event Tree Method and mentioned that this dam failure risk analysis model described was effectively applied to a specific water conservation project, yielding positive results. In addition to boosting flood season monitoring and increasing warning time, it is critical to reinforce the project. The other method utilized in dam risk assessments is Work Breakdown Structure (WBS). Reference [22] has done a study with this method. In this method Dam building work is divided into eight categories based on the process of developing this WBS standard: preparation, access road and bridge, cofferdam, tunnel and channel, main dam, spillway, intake, and public facilities which were provided clear vision to analyse the issue. Reference [23] suggests that sediment reduces the danger of river diversion during dam construction, and this effect is especially pronounced for high-assurance diversion projects using the Monte Carlo simulation (MCS) method. Reference [24] has taken advantage of the Geomorphology-Based Hydrological Model (GBHM) method. In their study in the Lancang-Mekong River Basin, the hydrological model combined with reservoir regulation (GBHM-LMK-SOP) realistically evaluated the impacts of dams on floods. As they found in their study, combining climate change and reservoir regulation, flood risk is reduced in the upper basin but the increasing flood amplitude and frequency from climate change still dominate in the lower basin.

As can be seen from the table above, many researchers tried to evaluate the risks related to the dam so they need to improve the monitoring issue which is one of the main items in the FMEA methodology. On the other hand, all of the papers tried to divide the issues into different parts to provide a better understanding.

2. OBJECTIVE AND METHODOLOGY

2.1. Study Area

One of the renowned dams in Iran is the Amirkabir dam (also known as the Karaj dam), which is a dam on the Karaj River in the Central Alborz mountain range of northern Iran. This dam, with a crest length of 390 meters and a height of 180 meters, formed a 4-kilometer-long lake [25]. The Amirkabir Dam was created to provide clean water to Tehran as well as agricultural growth in Karaj. Near Karaj, it meets the irrigation needs of roughly 50 000 hectares (120 000 acres) of farmland. The power plant, which has a capacity of 90 megawatts, has been connected to the national electrical network for over 46 years. Rainbow trout, a species in danger of extinction, can be found in the Amirkabir Dam's lake. This location is also a popular tourist destination due to its beautiful surroundings. Tehran's population is expected to reach 9 300 000 by 2022, indicating that the city will soon become a megacity, with the Amirkabir dam serving as its primary source of drinking water. Fig. 1 shows the study area's location.



Fig. 1. Location of Amirkabir Dam in Iran [25].

Since the intended study area, is an area with high environmental and ecological value and also has a variety of plant and animal species, beautiful landscapes, etc., and all these cases are somehow affected by the construction of Amirkabir Dam, this research has tried to investigate the environmental risks of Amirkabir Dam during the construction and utilization phases and to take the controlling measures to reduce and minimize the negative effects.

2.2. FMEA Method

An environmental risk assessment by the FMEA method is the process of qualitative and quantitative analysis of risk potentials in the project as well as the sensitivity or vulnerability of the surrounding environment. FMEA considers aspects of the environment and important

activities to improve the environment and on the other hand facilitates the conscious implementation of environmental activities. Environmental risk management involves making decisions about human activities or construction projects that have been affected by the environment or its consequences or effects on the environment. In these cases, decisions are made in a way that minimizes risks [26].

In this manuscript, it is tried to investigate the environmental risks in its construction phase and utilization period by FMEA (Failure mode effects analysis) method, and controlling actions have been proposed. The FMEA has been introduced as a credible technique among risk analysis techniques [27]. FMEA is a step-by-step approach for identifying all possible failures in the design, manufacturing, or assembly process of a product or service.

The purpose of the FMEA is to reduce the level of environmental effects and also a risk analysis of a developed process [28].

In descriptive research, the researcher seeks out how the subject is and wants to know what a phenomenon, variable, object, or subject looks like. To evaluate the environmental risks of Amirkabir Dam, first, the risk factors caused by this dam were identified, then to determine the severity and probability and detection of each risk and also to calculate the numerical value of risk, the FMEA failure factor analysis method was used. The steps of conducting the research are shown in the Fig. 2.

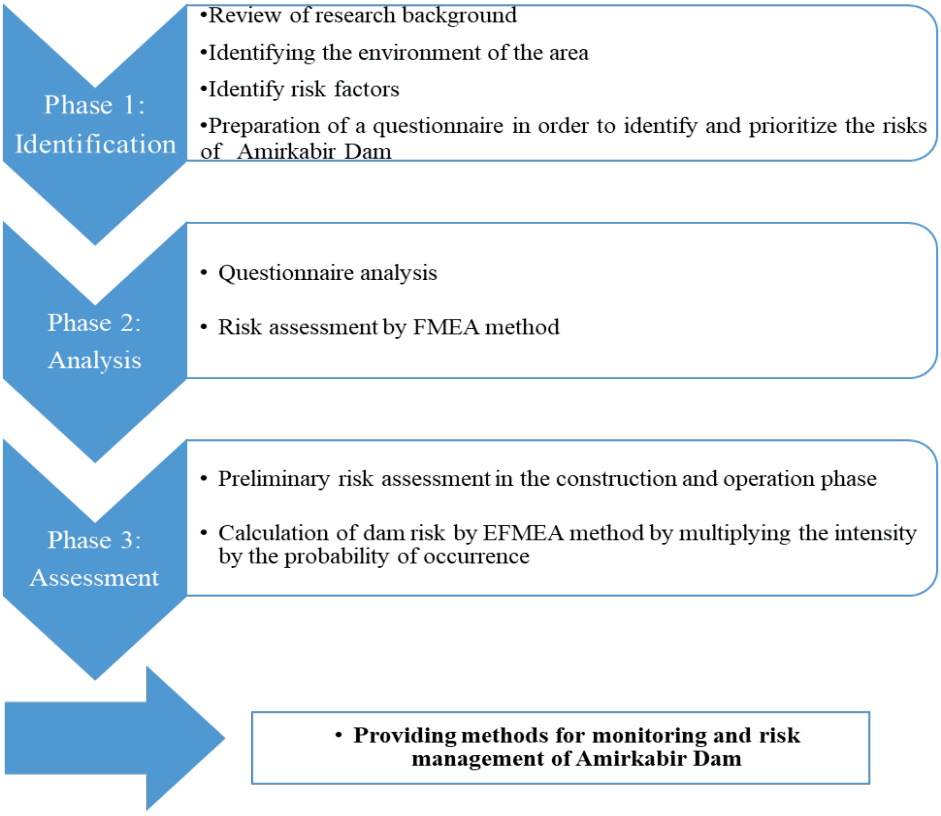


Fig. 2. Research model.

Methods and data collection tools:

After going through the legal process to be present in the area, the necessary permission was provided to access the available environmental information. The environmental situation was reviewed following the coordination.

In this study, to assess the environmental risk of Amirkabir Dam, the FMEA method has been adopted. Steps of this method are as follows:

1. Formation of FMEA group;
2. Processes identifying;
3. Potential failure mode (aspects);
4. Potential effects of failure (consequences);
5. Potential causes of failure;
6. Severity = S. Severity is an evaluation of the intensity of the effect and probable environmental failure points. Intensity is applied only to the effect and is ranked numerically between 1 and 10;
7. Occurrence – O. Occurrence is the frequency with which the cause of failure occurs. It should be noted that the numbers ranged from 1 to 10;
8. Detect = D. Detect is a kind of assessment of the level of ability that exists to identify a cause or mechanism of occurrence of a hazard. In other words, the probability of discovery is the ability to detect danger before it occurs;
9. Risk Priority Number = RPN. RPN is obtained by multiplying the severity, probability of occurrence, and detection: RPN = S·O·D. This value is used to rank the process steps and can be between 1 and 1000. For higher RPNs, group members should try to reduce it by corrective actions. In general, regardless of the amount of RPN, special attention should be paid to high-intensity cases. In general, a standard value for an RPN can be defined (for example, the number 100), and for environmental aspects that are above the standard value, measures can be proposed and implemented to reduce its RPN;
10. Proposed actions.

After prioritizing failure modes based on RPN value, corrective or preventive measures should first focus on priority and critical cases. The intention of any proposed action must be to reduce the rating of at least one of three cases of severity, occurrence, and detection. The risk identification via the RPN number has been shown in Table 1.

TABLE 1. RISK LEVEL DEFINITION OF EFMEA

Risk level	**RPN**
Low risk (L)	RPN < 116
Medium risk (M)	237.6 < RPN < 116
High risk (H)	RPN > 237.6

2.2.1. Method of Data Analysis

One of the most useful software for implementing the FMEA method is the PHA pro software designed and marketed by the Canadian DYDAM company. It can categorize data collected and give users useful information. Utilizing the FMEA technique and risk management are two of this software's key applications. FMEA evaluation has been carried out in this study using this program. Before calculating RPN based on the severity rating, the

chance of occurrence, and detection, environmental elements were first constructed and assessed in FMEA form in the Excel program. In this method, the level of vulnerability is determined first, and the factors based on the RPN risk priority number are given priority over the level of vulnerability and are regarded as vital activities that necessitate corrective actions in addition to data processing. Excel software and the chart's output have been used to assess factors for which the level of risk is higher.

Therefore, RPN was calculated using the FMEA method's tables, which are based on the seriousness of the consequence, likelihood that it will occur, and degree of contamination, or R. For RPNs higher than the threshold of risk, corrective steps were suggested.

3. RESULTS

In this part, the data collected from Amirkabir Dam are presented in the form of tables and diagrams. These data are the result of field studies, analysis of experts, as well as the study of documents in the relevant set of documents, which has been compared based on the FMEA risk assessment model.

3.1. Indirect Effects Range of the Project

In determining the scope of indirect effects of the project, according to the type of project and the dimension and effectiveness of its activities, the administrative boundaries of the region, including Alborz province, and the environment around the region in general, including the physical, biological and socio-economic aspects of the project, which indirectly affect the project in any way, is defined as the range of indirect effects of the project on the environment.

3.2. Direct Effects Range of the Project

In this regard, the main affected areas are permanent and seasonal rivers in the region, project area heights and rivers within the catchment area, plant and animal species, and habitats in general that will be changed as a result of the project. Local communities where settlements, agricultural lands, and their livelihoods are somehow affected by the project and also infrastructure facilities, including access roads, power transmission lines, etc., will be demolished or changed as a result of the project.

3.3. Environmental Effects Prediction at Different Stages of Construction and Operation

In general, environmental effects refer to the physical, chemical, biological, social, and economic changes in the environment as a result of one or more activities, and the identification of environmental effects is a major part of the process of environmental studies. Tourism plans and projects in the stages of preparation, implementation, and operation include several activities that affect the environment. The ultimate goal of implementing this method is to access a type of project that meets the optimal level of project objectives and also shows the best choice in terms of capacity, technology, engineering, etc. Environmental effects in the construction and utilization phases:

- Air quality;
- Quality of surface flow water and groundwater;
- Soil;
- Solid waste;
- Vegetation;

- Wildlife;
- Land use.

3.4. Analysis Results by FMEA Method

To assess the environmental risk of Amirkabir Dam by the FMEA method, after getting acquainted with the area and the process, the FMEA team was formed, and then the initial risk assessment was performed. Finally, after analysing the consequences of the identified aspects, the RPN risk priority number was calculated, and then control measures and secondary evaluation were performed.

3.4.1. Risks of the Dam in the Construction Phase

Annex Table 2 shows the environmental risk assessment of Amirkabir Dam according to the FMEA method in the construction phase of the dam.

Soil compression: The creation of resistant and impermeable layers in soil layers due to cutting-filling projects, and the activity of machinery and equipment will cause soil compression.

Exhaust gases from cars: With the launch of transport access roads, machinery gas emissions have increased to the end of the operation of the dam is dangerous 9. Due to the transient nature of vehicles and also the presence of vegetation left over from the destruction to build a dam, the severity of the impact on environmental parameters and air pollution is moderate 7.

In this case, the probability of its occurrence is partial and the severity of its effect is reduced, but the extent of infection does not change.

Excavation and embankment: Studies have shown that one of the risks arising from the operation of machinery and equipment is excavation and embankment, and as a result, soil erosion and pollution.

Working at height: Studies have shown that working at a height can increase the risk of falling from a height and endanger the safety and health of people.

Road construction: Activities such as soil compaction, blasting, and road construction have consequences such as loss of vegetation and wildlife habitat, disconnection between habitats in the area, and migration of species to other habitats. These destructive effects may occur during the construction phase of the dam.

3.4.2. Risks of the Dam in the Utilization Phase

Annex Table 3 shows the environmental risk assessment of Amirkabir Dam according to the FMEA method in the utilization phase of the dam.

Downstream sediment and erosion of the dam: According to the studies, most of the project area has low permeability, and the construction of the dam reservoirs and access roads requires the destruction of vegetation and pasture and this reduces soil permeability and thus exacerbates soil degradation and erosion. It is likely to occur by the end of the operation period and on the other hand, the effect of this sediment in the dam reservoir reduces nutrients downstream and also increases the erosion of the river walls. The result is environmental effects such as suffocation among fish due to gill filling and severity has a dangerous effect.

Oil leakage from equipment and machinery: According to studies, in the case of operation of machinery and equipment, oil leakage occurs due to traffic and the possibility of damage and non-standard equipment and machinery, which can affect the health of animals and endanger aquatic species.

Thermal stratification: The study indicates that the dam impoundment increases the surface temperature and the temperature difference causes thermal stratification. The results showed that the probability of occurrence of this phenomenon is moderate 5. Although there is no change in the severity.

Eutrophication: According to the results obtained by dam impoundment, conditions are provided for eutrophication in spring and summer. Therefore, it is likely that moderate pollution will occur by the end of the operation of the dam.

A comparison of risk assessment of the Amirkabir dam in the construction phase with the FMEA method is shown in Fig 3. As can be seen in this diagram, the highest risk in the construction phase of the dam is related to excavation and embankment, exhaust gases, and road construction.

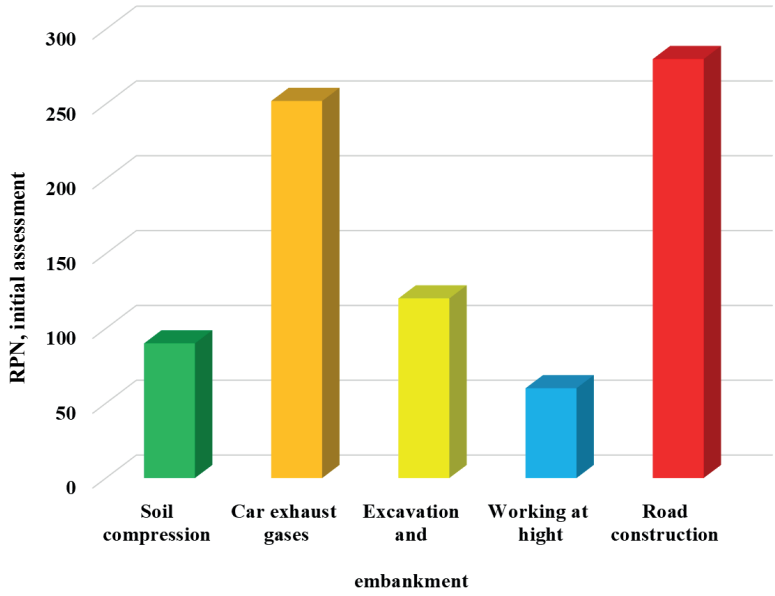


Fig. 3. Risk level assessment in the construction phase.

As can be seen in the diagram above, the highest amount of risk in the construction phase of the dam is related to excavation and embankment, exhaust gases from vehicles, and road construction.

Regarding soil compression, the evaluation shows that the risk level can be reduced if control measures such as planting and replacing suitable plants are carried out around the project area.

Control measures to reduce the risk of car exhaust gases are creating green spaces and installing filters. In this case, the probability of its occurrence and the intensity of its effect will be reduced, but the extent of contamination will not change.

Activities related to excavation and embankment have a moderate level of risk, but the level of risk and the intensity of its effects can be reduced by control measures such as measuring the amount of soil erosion and the use of mechanical soil protection structures.

To control the risk at height, the safety measures of the construction site should be increased.

For helping control road construction risks, reducing the amount of destructive road building activities, soil compaction, explosions, preventing the conversion of natural lands, etc. as control measures can reduce the extent of pollution.

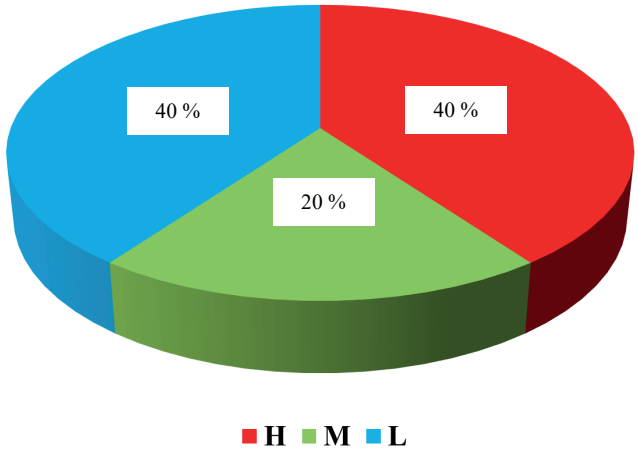


Fig. 4. Comparison of FMEA risk levels in the construction phase.

Most of the risks created in the construction of Amirkabir Dam are at the H and L levels, each of which has an equal share of 40 % of the total risks as is obvious in Fig. 4.

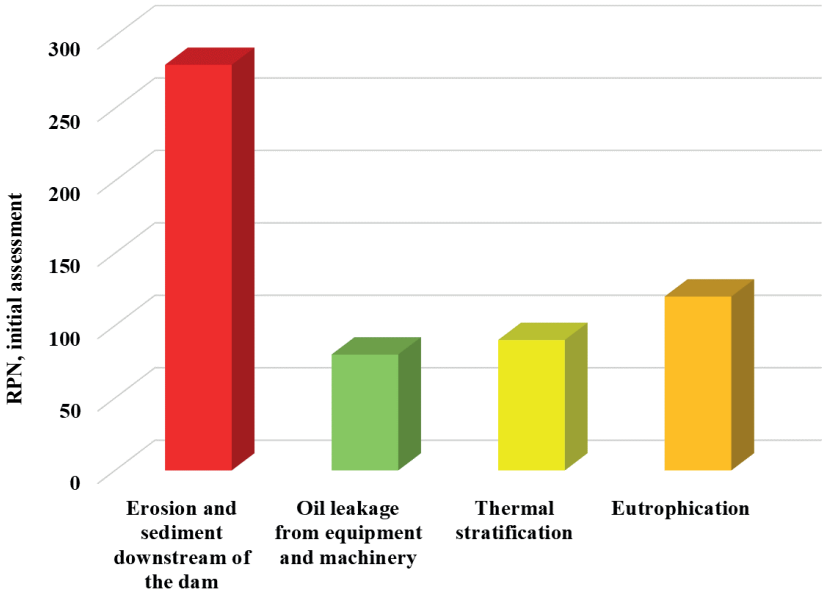


Fig. 5. Risk level assessment in the utilization phase.

On the other hand, in the utilization phase, it is depicted in Fig. 5 that the highest risk is related to erosion and sediment downstream of the dam and eutrophication.

Regarding the erosion and sediment downstream of the dam the measures that can be taken include minimizing the harvesting of materials and debris and creating suitable vegetation, in which case, after the control measures, the intensity of the effect, the probability of occurrence, and the extent of pollution will be reduced.

As can be seen, a moderate level of pollution occurs due to the traffic of machines, which in the case of implementation of control measures such as prevention of leakage and spillage of oil and fuel from devices to underground water sources, reduces the level of risk.

Control measures such as the release of water to mix water in the dam lake, construction of water exit valves at different heights of the dam wall, and water exit from different heights, reduce the risk level in thermal stratification. Although there is no change in the extent of pollution.

The measures that are taken to reduce the effects of eutrophication risk include the control of Mandab in the reservoir, the design of lower dischargers for the release of polluted water and organic materials, prevention of the entry of urban, rural, and industrial wastewater, which after the implementation of the measures, the intensity and the extent of the effect will be reduced.

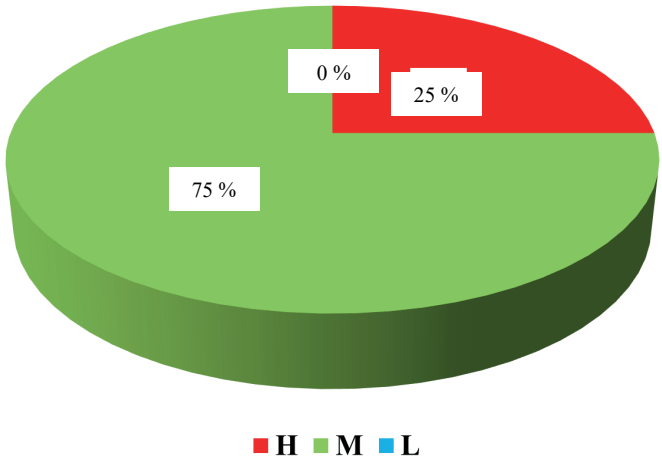


Fig. 6. Comparison of FMEA risk levels in the utilization phase.

As it could be found in Fig. 6, most of the risks created in the operation phase of Amirkabir Dam are at the M level, which accounts for 75 % of the total risks.

4. Conclusion

The construction of huge dams has significant environmental, biological, health, social, and economic consequences. Because of the rapid growth and development of dam construction around the world, particularly in Iran, it is critical to investigate the dam's environmental impact. A logical technique for assessing hazards is risk assessment, which evaluates hazards and their possible implications on people, materials, equipment, and the environment.

It provides valuable data for risk mitigation decisions, hazardous facility environment planning, emergency planning, acceptable risk levels, inspection and maintenance policies at industrial facilities, etc.

The outcome of this investigation showed the highest danger in the dam construction stage is identified with the road development and exhaust gases from vehicles with the risk priority numbers (RPN) of 280, and 252 separately and the most noteworthy danger in the activity stage is identified with getting territory abuse and borrow material overuse (disintegration and dregs downstream of the dam) with the risk priority number of 280.

After providing measures and solutions to prevent, reduce and control adverse environmental risks caused by the construction of Amirkabir Dam, establishing management and environmental monitoring programs, under national and international guidelines, for accurate and basic monitoring of operations, processes and actions are necessary. One of the main goals of management and monitoring programs is to perform audit and self-inspection operations to minimize adverse direct or indirect environmental consequences during construction activities. To reduce the effects of Amirkabir Dam risks in the construction phase, corrective measures are proposed:

- Prevention and control of air, water, and soil pollution in the affected area during the operation period;
- Preventing excessive consumption of water resources and severe decline in groundwater aquifers in the region;
- Improving the economic and social situation of the residents around the dam to attract their participation in the protection of the environment of Amirkabir Dam;
- Reducing potential human, health, and environmental hazards due to utilization activities;
- By using earth dams and low dams, it is possible to overcome the need to use huge dams with large reservoirs, which naturally have more effects on nature, and reduce the negative effects of these huge structures;
- Take the results of environmental assessments seriously and act on them to reduce the destructive effects on the environment;
- Planting trees and restoring vegetation in the areas around the dam;
- Protection of aquatic animals especially rainbow trout and red-spotted trout and their spawning grounds and development of aquaculture and fisheries facilities.

The utilization of the FMEA contributes to the ceaseless change of the occasion in terms of security and quality by taking vital measures to oversee the chance. Eventually, this paper tried to conduct a case study under the FMEA risk assessment method to investigate the utilization of this method in a specific mega project to provide a better understanding of the advantages of this issue which can help HSE (Health and Safety Executive) engineers in the future.

ANNEX

TABLE 2. ENVIRONMENTAL RISK ASSESSMENT TABLE OF AMIRKABIR DAM BASED ON FMEA IN THE CONSTRUCTION PHASE OF THE DAM

Activity	Potential failure modes	Potential causes of failure	Potential failure effects	Initial assessment					Controlling actions	Secondary assessment				
				Intensity	Occurrence	Detect	RPN	Risk Level		Intensity	Occurrence	Detect	RPN	Risk Level
Machinery activities and equipment	Soil compression	Agricultural development and heavy machinery traffic	Creating an impermeable layer in the subsoil	6	5	3	90	L	Planting and replacing suitable plants around the project area	5	3	3	45	L
	Car exhaust gases	Emission of pollutant gases	Air pollution	7	9	4	252	H	Filter installation Green area creation	6	5	4	120	M
	Excavation and embankment	Soil contamination	Soil erosion	6	5	4	120	M	Measuring the rate of soil erosion Use of mechanical soil protection structures	5	5	3	75	L
Safety	Working at height	Falling from height	Death or injury	5	4	3	60	L	Strengthen the HSEQ team of the project and improve the safety tools and criteria	4	4	2	32	L

Road construction	Road construction	Destructive road construction activity	Loss of vegetation and wildlife habitat, disconnection between habitats in the area, migration of species to other habitats	10	7	4	280	H	Reducing the volume of destructive road construction activities, soil compaction explosions and prevention of natural lands use change, etc.	7	5	4	140	M

TABLE 3. ENVIRONMENTAL RISK ASSESSMENT TABLE OF AMIRKABIR DAM BASED ON FMEA IN THE UTILIZATION PHASE OF THE DAM

Activity	Potential failure modes	Potential causes of failure	Potential failure effects	Initial assessment					Controlling actions	Secondary assessment				
				Intensity	Occurrence	Detect	RPN	Risk Level		Intensity	Occurrence	Detect	RPN	Risk Level
Excavation of borrow material	Erosion and sediment downstream of the dam	Destruction of vegetation	Destruction of plants in the reservoir downstream of the dam Extinction of animals Extinction of fish due to gills being filled with sediment	10	7	4	280	H	Minimize the withdrawal of materials from borrow area Creating suitable vegetation	7	6	3	126	M

Use of vehicles and machinery and	Oil leakage from equipment and machinery	Damage to equipment and machinery as well as vehicles active in the area	Soil and water pollution and impact on animals and aquatic life	8	5	2	80	M	Prevention of direct discharge of human effluent and prevention of leakage and separation of oil and fuel devices to groundwater sources Installation of wastewater treatment systems	4	3	3	36	L
Impoundment of the dam	Thermal stratificatio n	Differences in density and temperature of the upper and lower layers of water	Food exchange and soluble gases, especially oxygen, do not take place between reservoir water layers.	6	5	3	90	M	Measuring the rate of soil erosion Use of mechanical soil protection structures	6	3	3	54	L
Road construction	Eutrophicat ion	Leaching of chemical fertilizers containing phosphorus and nitrogen and release of industrial, urban and rural effluent	Loss of water quality	6	5	4	120	M	Reducing the volume of destructive road construction activities, soil compaction Explosions and Prevention of natural lands use change, etc.	5	4	4	80	L

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