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Risk Assessment of Water Transmission Pipelines with Fuzzy FMEA-AHP Approach (Case study: Yazd Water Transmission Pipeline)

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ABSTRACT

As vital matter, water plays important role in human life. Water transmission pipeline of Zayanderood to Yazd is one of the most important structures for potable water supply in seven cities of Yazd province. As water sources in the province don't provide drinking water from quantitative and qualitative aspects, any disturbance in utilities of this pipeline can endanger water supply and its outcomes are based on social and political problems. Thus, it is necessary to identify potential and actual errors before occurrence. The present study presents a new methodology to use "failure mode and effects analysis" technique to mitigate the risk of water transmission pipeline to Yazd. The failure types in this pipeline are detected via the opinions of organizational experts, then "likelihood of occurrence", "error severity" and "predictability before occurrence" can be weighted by fuzzy AHP and finally by RPN index, the required elements are ranked. As verbal evaluation is performed as approximate by people, fuzzy logic is used for contradiction with the uncertainty of this type of evaluation. The results of study show that "failure of electromotor and electricity panels in pumping stations, reduction of height of river water level in water harvesting site and breakdown of main faucets in pipeline path are on high priority.

KEYWORDS: Risk, Water transmission, Fuzzy, FMEA, AHP.

1. INTRODUCTION

The analysis of potential failure modes of a system or a machine is an efficient method to evaluate system to increase system efficiency and increase of user safety. An important and practical technique to identify and rank potential and actual factors of failure is FMEA. By identification and ranking of error factors, we can eliminate or mitigate them and increase durability and reliability of system and reduce maintenance costs. The existing models of quality improvement focus on existing condition of elements in institutions and the most important elements are identified finally and this leads to quality improvement but the suitable approach is prevention of failures in system and besides reducing quality, loyalty and commitment of current customers are threatened severely and the application of goods and services can be stopped. Thus, it is required to identify these failures considered as failure to meet suitable quality level and to evaluate scientifically to pass the most sensitive stage for quality improvement (Abadian, 2011).

Water is vital in life and achieving suitable drinking water and health is one of the primary requirements. As water resources don't exist everywhere, water should be transmitted to consumption site. Being located in desert area, Yazd province is encountered with serious water shortage. To compensate a part of required water for drinking and health, water is transmitted by a pipeline and utilities in 1999 from Isfahan to Yazd province. Now, seven provinces of Yazd are dependent upon this pipeline. Based on the importance of this pipeline as one of the most important infrastructural utilities of province, it is necessary to use new management techniques for operation and maintenance of this strategic structure. The most important action is detection and assessment of risks of this pipeline. One of the highly practical techniques in detection of failure before occurrence is FMEA. Systematically, this technique by severity× occurrence ×detection for each item rank failure and final value is called risk priority number (RPN). Indeed, the higher this item, the higher the priority of the index and the managers should put it on priority in their planning. In other words, ranking potential and actual failures in water transmission pipelines to Yazd presents the priority of their improvement well. This information can be the basis of the quality improvement planning. The importance of each of the items is investigated and applied in the final result. Also, fuzzy hierarchy analysis technique is used to define the difference between three items of severity, occurrence and detection. The present study attempts to apply fuzzy approach in most researches to reduce ambiguity in the qualitative variables and people opinions are involved in it.

2. REVIEW OF LITERATURE

Current organizations apply failure modes and effects analysis and are sure they present a product without any failure or failure to market. By this efficient tool, we can detect and prioritize potential modes of failure in system, process, product and service. Also, by this tool, we can define and determine required actions to eliminate or mitigate occurrence of failure potential modes and finally the results of analyses can be registered with the aim of providing a complete reference to solve the future problems (Dabiri et al., 2002). Failure mode and effects analysis approach is a procedure by which a suitable structure is formed for evaluation and updating design and development of process and all

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policies in organization. The goal of Failure mode and effects analysis is prevention of problem occurrence. In other words, by optimizing processes and products, great costs are reduced (Barney, 2001). This approach is a systematic method focusing on prevention of failure, increasing safety and customer satisfaction (Carr, 2001).

Generally, the main purpose of failure modes and effects analysis is detection and prioritization of potential failure modes by calculation of risk priority degree index (Segismundo et al., 2008). Risk priority number is criticized widely and its important item is considering equal importance for three factors and providing definite response to failure items (Bowles, 2004. Fuzzy approach and fuzzy AHP technique are used to solve these problems.

Various studies have been conducted regarding FMEA technique in industry and various methods are used for detection and ranking of risk factors as follows:

Sharma et al., (2005) in a study in paper industries compared the results of traditional and fuzzy FMEA methods with each other and found that in fuzzy method, expert opinions can be involved in evaluation better and are flexible compared to traditional method (Sharma et al.,2005).

Sardar et al., (2009) assessed risk by FME&CA method on transmission, storage and loading operation pipelines of crude oil in terminal of Khark. This study showed that the failure severity and likelihood of occurrence and criticality of system were low and the major reason was suitable maintenance in oil terminal site. RPN of loading and supports failures is low compared to other failures of oil transmission system. The most important failures in oil transmission system include blockage of pumps filter (RPN=175 and criticality 1), pipes abrasion (RPN=140 and criticality 2), failure of pumps driving force (RPN=140 and criticality 2), pipes corrosion (RPN=128 and criticality 3)(Sardar et al., 2009).

Amiri and Nasiri conducted a study "application of FMEA fuzzy approach to evaluate failures risk of signalling, signs, control and telecommunication of subway. In this study RPN was calculated by two approaches "fuzzy system based on rules" and "theorization" and in both approaches, similar results were achieved (Amiri and Nasiri, 2009).

Abadian in a study "evaluation of services quality with failure and effects analysis and fuzzy data envelopment" in cooperative company of Pishgaman of Kavir Yazd identified 32 items as failure factors in DSL services. Ranking of failure items showed that line speed drop due to traffic increase, limited bandwidth of Infrastructure Company or malicious shared system and problem of shared internal line had highest priorities (Abadian, 2011).

Sokhakian and Moeini (2011) in a study for risk assessment of water transmission projects in water and wastewater company of Fars province by FMEA technique, calculated RPN, NRPN (RPN with sensitivity analysis) for various risks and found that NRPN calculation had high accuracy to determine risk number (Sokhakian and Moini, 2011). Qanbari et al., (2012) in a study to determine risks of oil and gas transmission lines by FMEA method found pipe corrosion due to fluid impurities sediment with RPN=400 and cracking due to incorrect design with RPN=80 were the highest and lowest risks (Ghanbari et al., 2012).

3. STUDY METHOD

The present study is applied in terms of purpose and survey in terms of implementation and is also cross section method with the aim of ranking failure items in regional water company of Yazd. To achieve exact results, various sectors of water transmission pipelines to Yazd are visited. The maintenance of equipment records was investigated. A questionnaire was provided by achieving the opinions of experts. Validity of questionnaires is verified by content validity. The final data were collected by interview and completion of questionnaire. The study population was managers, experts and technical forces of water transmission of regional water company of Yazd. The inclusion criteria of selecting experts were BA degree and five years of activities in this field. The number of samples was total 19 experts. FMEA and fuzzy AHP methods were applied.

3.1. Failure and effects analysis

Current systems of goods and services production are with failure and failures and disorders of sudden failures in these systems are unavoidable. Technological progresses of goods and services production systems have made the work of system analysts challenging and obliged them to use some techniques as failure modes and effects analysis for detection, measurement and analysis of system behaviour. Current organizations apply failure mode and effects analysis and are sure a product without failure is presented to market. By this efficient tool, we can detect and prioritize potential failure modes in system, process, product and service. The required measurements for elimination or mitigation of potential failure modes occurrence can be defined and finally the results of analyses can be registered with the aim of providing a complete reference to solve the future problems (Dabiri et al., 2002). Failure mode and effects analysis approach is a procedure by which a suitable structure is formed for evaluation and updating design and development of process and all policies in organization. The goal of Failure mode and effects analysis is prevention of problem occurrence. In other words, by optimizing processes and products, great costs are reduced (Barney, 2001). This approach is a systematic method focusing on prevention of failure, increasing safety and customer satisfaction (Carr, 2001).

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FMEA was presented for the first time by NASA organization in 1963 and then it was developed by Ford automotive company in 1977. This technique aimed to detect and modify potential problems during design and production stages (Chang et la., 1999). The failure factors and effects analysis approach reduce re-works and modification actions. Failure factor and effects analysis is a dynamic method as executed permanently. Thus, it is not a process to be finished only by once time implementation. This process with other activities of company is as current duty of company members (Sharma et al., 2008).

The first stage of failure analysis technique is as all members have similar recognition of process and their duty and the people in group should be aware of the entire process. This leads to the detection of potential failures, effects and solutions (Dabiri et al., 2002). There are three risk factors to define risk priorities including failure impact severity (S), failure occurrence likelihood (O) and detection (D). RPN is based on multiplication of severity, occurrence and detection and a high risk priority score indicates high risk (Chang and Paul, 2009). Severity factor is a rank indicating criticality of potential failure mode of system. Severity is evaluated from all aspects including failure impact on system, other systems, customer, product or state rules (Dabiri et al., 2002). Each of the items is ranked based on scale 1 to 10 and rank 1 is the lowest and rank 10 is the highest. The important point is presenting a definite definition for each item on scale as perceived for all people similarly (McDermott et al., 1996). Occurrence factor indicates frequency or cumulative value of failures for a specific reason in a time period. In other words occurrence rank indicates the likelihood of occurrence of failure. To compute occurrence rank, we can estimate the number of failures during life service for thousands or 10 thousands of services or achieve estimation of failure occurrence likelihood during life service (Dabiri et al., 2002).
Detection factor is the chance as current control methods can detect failure mode or failure occurrence reasons in service before being achieved by customer or service is completed. To rank detection, the ability of each of current control methods in detection or failure prevention before being achieved by customer is estimated (Dabiri et al., 2002). As evaluation of three factors is not easy and verbal assessment is approximate, triangular and trapezoid membership functions are suitable to avoid the ambiguity of these evaluations and the attempt to achieve exact values is impossible and unnecessary (Delgado, 1998).

3.2. Fuzzy hierarchy analysis

AHP method is one of the multi-criteria decision making techniques developed by Thomas Saaty in 1980. This method is used when decision making is encountered with some decision making criteria and attributes (Saaty, 1980). AHP enables the combination of qualitative and quantitative criteria at the same time. AHP is based on pairwise comparison of decision making criteria. For such comparison, data is collected form decision makers and this enables the decision makers to focus on two criteria or attributes ignoring any external influence (Saaty, 1989).

3.3. Fuzzy theory

Fuzzy sets theory was presented for the first time by Professor Lotfizade and was applied in solving the problems in which parameters and quantities couldn't be stated exactly. Fuzzification depends upon different types of uncertainty namely linguistic and attitude expression and it is different from the uncertainty stated by probability theory. Fuzzy approach is a suitable tool to deal with uncertainty and modelling linguistic variables (Mohammadi et la., 2012). Fuzzy logic is aimed to provide a basis for approximate reasoning by fuzzy set theory. As human decision making is with uncertain concepts, these concepts are expressed by linguistic variables. Based on fuzzy logic, these inexact elements are important factors in human intelligence (Kwongc.k., H.A Bai, 2002).

Triangular fuzzy number is special type of trapezoid fuzzy number and is famous in fuzzy applications. A triangular fuzzy number is shown by three numbers (m, l, u) and membership function $\mu A(x)$ in chart 1.

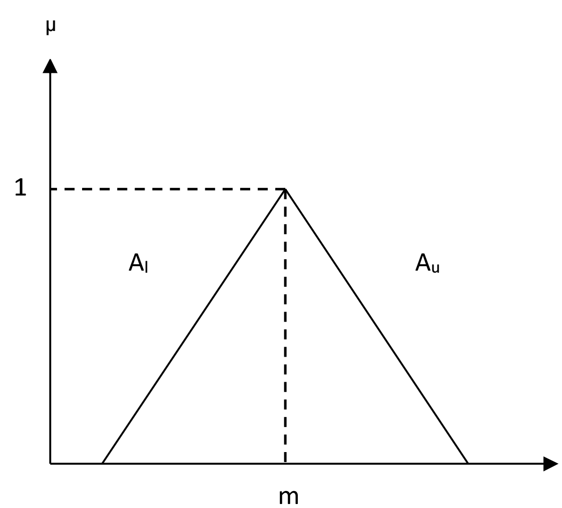

Fig. 1. Numerical view of triangular fuzzy as three components

As A1 is left spread and Au, right spread of triangular fuzzy numbers (Qazifard et al., 2012).
FAHP methodology is developed by combining AHP of Saaty and fuzzy set theory. This methodology is designed to select an attribute and verification of problems by integrating the fuzzy set concepts and AHP. The main idea in AHP is

achieving the knowledge of experts to the studied phenomenon. The application of fuzzy methodology enables the decision maker to integrate qualitative and quantitative data in decision model. Traditional AHP cannot reflect the processes well (Azar and Rajabzade, 2010).

3.4. Water transmission pipeline to Yazd

Water transmission pipeline to Yazd with length 333km transfers water from Cham Aseman dam located in Baghbahadoran of Isfahan to Yazd province. This complex is with four pumping stations with capacity 3m3/s with pumping height of 140m, a water treatment plant with capacity $3.6m^3/s$ and seven stations of reservoir with the sum of storage capacity $280m_3$. The pipeline is steel and in each pumping stations, there are four electro pump devices.

To define failure choices in water transmission pipeline, at first a meeting is held separately with the authorities of pumping stations, water treatment plant, line and reservoirs and finally 68 items are determined as shown in Table 1 as failure factors.

Table 1. The list of failure factors of water transmission pipeline to Yazd

No	Risk	No	Risk
1	Power outage of pump stations	35	Drain valves failure in pipeline
2	Power outages of treatment plant	36	Failure of shut-off values of line
3	Power outages of reservoirs	37	Failure of air valves of pipeline
4	Loss of pumping electricity voltage	38	Internal corrosion of pipeline
5	Reduction of river water level	39	External corrosion of pipeline
6	Increasing river water opacity	40	Corrosion of valves and connections
7	Leaf and wood in river	41	Failure of cathodic flow injection system
8	Contamination of river water	42	Corrosion of anodic ground of cathodic system
9	Malfunction in pipeline	43	Failure of main electricity panels of water treatment plants
10	Robbery of equipment and parts	44	Failure of *chlorination* system of water treatment plant
11	Reduction of water allocation	45	Failure of injection equipment of chemical materials of water treatment plant
12	Flood	46	Failure of balancing system of filters water discharge
13	Earthquake	47	Failure of pulsator vacuum pumps
14	Failure of electromotor	48	Failure of command of filters washing
15	Failure of pumps	49	Failure of filters air blowers
16	Failure of pump chargers	50	Failure of compressors of filters air
17	Failure of water treatment plant chargers	51	Failure of pneumatic faucets of filters
18	Failure of reservoir chargers	52	Failure of compressed air system command panel
19	Failure of one-way pumping valves	53	Failure of recovery unit pumps
20	Failure of control valve of outflow discharge of pumping	54	Failure of chlorine injection pipeline of crude water
21	Failure of pumps suction valve	55	Failure of treated water chlorine injection pipeline
22	Failure of pumps discharge valves	56	Failure of sludge purification of pre-deposition units
23	Failure of compressor and	57	Failure of sludge blow down valve of pre-deposition units
24	Failure of main electricity panel of pumping	58	Failure of pulsator entrance valves
25	Failure of panel of each of pumping engines	59	Failure of chlorine injection system of reservoirs of line
26	Failure of pumping low pressure trans	60	Failure of plc panels of pumping stations
27	Failure of pumping medium pressure trans	61	Failure of plc panels of reservoirs
28	Failure of water treatment plant trans	62	Failure of telemeter telecommunication equipment
29	Failure of additional transformers of basin	63	Failure of monitoring system of pumping stations
30	Failure of basin sludge pumps	64	Failure of monitoring system of water treatment plant
31	Failure of basin inflow valves	65	Failure of monitoring system of Yazd control center
32	Disposition in basin channels	66	Failure of Instrumentation equipments of treatment plant
33	Failure of needle valves of reservoir inflow	67	Failure of Instrumentation equipments of pumping
34	Pipeline bursting	68	reservoirs equipment's instruments failure

In the next stage, the questionnaires of failure items and weight of risk factors are provided. For validity of questionnaires, academic experts' opinion is used. Then, the questionnaires are sent to experts of company. The experts defined their agreement for each of failure items based on defined verbal variables. Verbal variables to determine the importance of failure items are shown in Table 2.

Table 2. Verbal variables for the importance of failure items (Yang, 2005)

Verbal variables	Triangular fuzzy number
Very much	(0.75, 0.9, 1.0)
Much	(0.55, 0.70, 0.85)
Average	(0.35, 0.5, 0.65)
Low	(0.15, 0.3m 0.45)
Very low	(0.0, 0.1, 0.25)

To achieve unit criteria in verbal variables of each of risk factors, these variables are defined in Table 3:

Table 3. Explanation of verbal variables for risk factors

Likelihood of occurrence
Very low: It is occurred averagely once a year.
Low: It is occurred averagely some months.
Average: It is occurred each month.
Much: It is occurred averagely each week
Very much: It is occurred averagely each day.
Impact severity
Very low: It has no effect on water transmission flow continuity.
Low: Water transmission capacity is reduced to 10% or if it is not removed during some weeks, it creates another failure.
Average: Water transmission capacity is reduced by 30% or if it is not removed during some days, it creates another failure.
Much: Water transmission capacity is reduced to 30 and 70% or if it is not removed in some hours, it creates another failure.
Very much: It leads to water flow cutting.
Likelihood of detection
Low: It needs specific tools or lab test.
Average: It is diagnosed by normal measurement tools.
Much: It is defined in case of visiting equipment
Very much: The operator can find in occurrence.

To determine the weight of risk factors as “likelihood of occurrence”, “impact severity” and “likelihood of detection”, Chang development analysis is used and based on the limited pages, the steps are ignored. To convert crisp numbers to fuzzy for pairwise comparison, Table 4 is used.

Table 4. The scale of converting fuzzy triangular (Azar and Rajabzade, 2010)

Fuzzy triangular inverse scale	Fuzzy triangular scale	Verbal scale
(1,1,1)	(1,1,1)	Equal
(2.3, 1, 2)	(1.2, 1, 3.2)	Important equality
(1.2, 2.3, 1)	(1, 3.2, 2)	Low importance
(1.3, 2.5, 2.3)	(3.2, 5.2, 3)	Much importance
(1.3, 2.5, 1.2)	(2, 5.2, 3)	Very importance
(2.7, 1.3, 2.5)	(5.2, 3, 7.2)	Strong importance

4-Data collection and data analysis

The weight of each of risk factors after receiving the opinion of respondents in the form of questionnaire by pairwise comparison in FAHP method is shown in Table 5.

Table 5. The weight of risk factors (FAHP)

Risk factors	Fuzzy weight of factor		
Likelihood of occurrence	0.253	0.341	0.624
Impact severity	0.533	0.672	0.813
Likelihood of detection	0.034	0.102	0.28

Based on the results in the above Table, “impact severity” factor has the highest weight. The next impact in increasing risk rank is “likelihood of occurrence”. The lowest weight is about “likelihood of detection”.

To calculate risk number of each of failure factors, at first fuzzy mean of respondents’ opinion is calculated for each of factors. Based on questionnaire questions and defined linguistic variables, fuzzy mean of each of components is calculated based on the following relations (Mirsepasi et al., 2010):

$$A^i = (a_1^{(i)}, a_2^{(i)}, a_3^{(i)}), \quad i = 1,2,3,\ldots,n \tag{1}$$

$$A_{ave} = (m_1, m_2, m_3)$$
$$= (\frac{1}{n}\sum_{i=1}^{n} a_1^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_2^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_3^{(i)}) \quad (2)$$

In equation 1, A^i indicates expert i[th] opinion and in equation 2, A_{ave} is the mean of experts' opinions. a_1, a_2, a_3 Indicate triangular fuzzy number. Then, by multiplication of factors weight (Table 5) by fuzzy mean of each of factors, their weighted mean is calculated. By the multiplication of given weight fuzzy means of each of risk factors, RPN fuzzy number is obtained. To turn fuzzy RPN to crisp RPN, equation 3 is applied (Yung, 2006).

$$X = (a_1 + 4 * a_2 + a_3)/6 \quad (3)$$

All calculations are performed in Excel and by applying above formulas.

After the calculations of risk number of each of failure factors in water transmission pipeline, the results are ranked. Based on the results "failure of electromotor" with risk number 8.73 has the highest rank and "PLC panel failure of reservoirs" with risk number 2.32 has the lowest rank.

20 Cases of water transmission pipeline failure factors with the highest risk number are shown in Table 6.

Table 6. 20 Cases of water transmission pipeline failure factors with the highest risk number

Risk number	Risk name
8.73	Failure of electromotor
8.54	Failure of panel of each of pumping engines
8.25	Reduction of river water level
7.63	Failure of shut-off valves of line
7.54	Failure of one-way pumping valves
7.08	Drop of pumping electricity voltage
6.98	Failure of pumping discharge valves
6.70	Cutting of electricity of pumping stations
6.63	Pipeline bursting
6.54	Contamination of river water
6.48	Malfunction in pipeline
6.45	Failure of water blow down valves of line
6.44	Failure of air valves of pipeline path
6.43	External corrosion of pipeline
6.39	Increasing river water opacity
6.38	Failure of chlorination system of water treatment plant
6.28	Failure of main electricity panels of pumping
6.16	Failure of telemeter telecommunication equipment
6.13	Failure of pumping chargers
6.08	Failure of chemical materials injection equipment of water treatment plant

5. DISCUSSION AND CONCLUSION

Based on the results of risk assessment of failures of water transmission pipeline to Yazd, it can be said that failure in electric equipment of pumping stations, reduction of height of river water and failure in valves in transmission pipeline path and in pumping stations are the most important risks of water transmission pipeline to Yazd. It is attempted to apply the opinions of managers and experts in water transmission pipeline in assessment results analysis. It is worth to mention that in assessment of water transmission pipeline risks, not only full cutting of water flow is considered, but also the lack of achieving allocated water share and capacity is considered. In this assessment, failure of electromotors has the highest rank with risk number 8.73. This result is supported in interview with managers and technical experts. One of the most important factors of increasing these statistics is increasing life service of systems, type of launching system connection to electromotor rotor. In this launching system, after electromotor reaches nominal rotor rpm, brush lifting system equipped to electric operator short circuited rotor by a disc and resistance starter is separated from rotor. This launching system design is dedicated to Siemens Company and its advantage is eliminating coal erosion and coal powder distribution in electromotor windings. Thus, engine combustion probability is reduced and the important point is the exact balance of short circuit and suitable performance of springs. Over time, elasticity of spring is reduced and short circuit disk is imbalanced. Thus, in short circuit path of rotor, a very small hole is created. Due to high current (about 600

A) at this point, strong sparkle is created and electromotor is stopped. Generally, the increase of probability of this failure, using specific system of launching system connection to electromotor, lack of technical support of Siemens Company due to sanction, limited number of high pressure electromotor maintenance in the country and low experience of existing maintenance companies of high pressure electromotor are important in repairing this type of connection. Regarding the high failure impact severity, we can refer to the lack of electromotor maintenance in station and transferring to valid maintenance companies and long maintenance time of a device and failures of other pumping stations as other electromotors, pump, command panels and etc. during this period, second reduction of capacity of other pumping stations in case of reduction of pumping capacity in a station and third high costs of maintenance in each electromotor device. High failure risk number of power panels of electromotors is due to the uncertain performance of some of power keys of these panels. Due to the operation conditions or other risks in transmission line, turning on and off cases of engines and shut-off of these switches are high and keys depreciation is increased.

Another important risk in water transmission pipeline is reduction of river water level in harvesting site. The most important reason is reduction of rainfall in Zayanderood river watershed. The second factor is the river water height being influenced of harvesting plan of other water consumers in the site. The above risks have average likelihood of occurrence. Fourth risk is failure of faucets in pipeline. The reason of high rank of this risk despite its low likelihood of occurrence is its high impact severity. As in case of occurrence, it leads to full cutting of water flow and a part of pipeline water should be emptied to remove its problem and removing the failure is time-consuming. Some of the risks have low or very low likelihood of occurrence and their impact range is very much and water is stopped for some days. Based on the 15 year operation history of water transmission, three cases of full cutting of water with average time 25 hours for pipeline bursting, water cut with 117 hours due to river water contamination with oil materials and two-week cutting of water due to colliding pipeline and fire of one of pumping stations are occurred. These risks rank 9-11 in ranking Table. Water cutting flow is for planned maintenance and modifications with 2 to 11 days (4 cases).

Based on the findings of study, the study result is presented as two sections. First section is based on FAHP technique and it is shown severity item has highest importance as this item has unavoidable problems. Also, occurrence item and finally detection are in next ranks. Second conclusion is shown in Table 6 in which the items are ranked by RPN. According to this Table, "failure of electromotor and their power panels in pumping stations, reduction of river water level in water harvesting site and failure of main faucets in pipeline" have the highest priorities. Based on this issue, we can refer to the importance of the role of electromotors. To reduce risk of this item, by purchasing and increasing the number of spare electromotors and definition of research project for high pressure electromotor maintenance companies regarding the modification of resistance starter circuit system to electromotor rotor, failure rate and its severity can be reduced. Regarding electricity panels of electromotors, using the services of specialized companies in service and their overhaul or changing the type of power keys can be effective solutions. Regarding the loss of river water level height, modification of water inflow channel path to pumping unit is on priority for company. It is worth to mention that based on the maintenance system based on ISO quality management system 2008 in water transmission pipeline, prediction of reserve equipment and utilities and timely action to maintain failure equipment of full cutting of water can be occurred in rare periods. The factors with low likelihood of occurrence have high impact severity as pipeline bursting, river contamination and malfunction should be in planning of risk number reduction.

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